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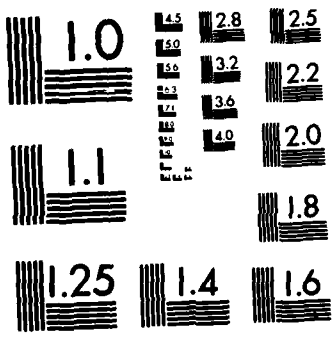
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Methodology for Analyzing the Effect of Hydrometeorology

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Goes Random Data Collection

August 1982

US Army Corps of Engineers
New England Division

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A methodology and guidelines for the design of a randomly reporting network of data collection platforms is given. The system assumes the use of GOES satellites as retransmitors. A full review of the communication literature dealing with random and contention protocols is included. Also included is an analysis of extensive daily precipitation records over the conterminous United States leading to probabilistic statements of rainfall occurrence.

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A METHODOLOGY FOR ANALYZING THE EFFECT OF HYDROMETEOROLOGY OF THE CONTIGUOUS UNITED STATES ON THE GOES RANDOM DATA COLLECTION SYSTEM

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August 1982

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New England Division
424 Trapelo Road
Waltham, MA 02254

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WATER CONTROL BRANCH

Preface and Acknowledgements

Contract DACW33-82-C-0011, entitled "Research and Preparation of a Report on the Application of GOES Random Data Collection to Hydrometeorology of the Contiguous United States," was awarded on December 30, 1981, by the Department of the Army, Corps of Engineers. The scope of work called for the development of guidelines for data collection network design when Data Collection Platforms respond to random climate inputs throughout the United States. Basically, the idea was to evaluate to what extent DCPs in different regions in the United States can interfere with each other because they are simultaneously excited by storms. The contract called for an analysis based on published or existing climatic theories.

During the course of the work it was apparent that analysis of an existing raw data set could be fruitful. The decision was made to embark in this direction and the results corroborate the wisdom of the move. It was not smooth sailing, though. The problems and tribulations of handling the massive amount of data with limited computer power almost proved fatal. But it was done.

Many thanks are due to several individuals. Foremost Mr. Tim Buckelew and the staff of the Water Control Branch of the New England Division were invaluable in providing help and being available when needed. They received us warmly in the midst of their office and operation. Ms. Ellen Rolfe and the Smithsonian Institution gave us tremendous assistance in surpassing some terrible computer compatibility problems. Dr. Harry Glahn and his staff in the Techniques Development Laboratory, National Weather Service, provided the precipitation data necessary for the analysis. Finally, Ms. Elaine Healy did a wonderful typing job throughout the many revisions of this document.

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PROLOGUE

The Geostationary Operational Environmental Satellite (GOES) data collection system operated by the National Earth Satellite Service (NESS) of the National Oceanic and Atmospheric Administration currently supports data collection from several types of data collection platforms (DCPs). With the advent of adaptive random reporting platforms, several potential procedural and technical problems associated with effective network design have been recognized. This project is intended to address these issues with regard to the configuration of networks of random reporting data collection platforms used to record flood and flood producing events. Chapter 1 gives a general overview and problem statement. Chapter 2 overviews DCP operation equipment and users experiences. Chapter 3 focusses on evaluation of the basic theory of random reporting in the telecommunications tield in order to theoretically investigate channel performance characteristics for random modes of operation. Chapter 4 presents the theory behind the proposed data collection network design algorithm. The available climatological data is discussed in Chapter 5 and Chapter 6 is a hypothetical case study to illustrate use. The Appendices contain user manuals and listings of related computer programs.

CHAPTER I

Introduction

1.0 Introduction

The Corps of Engineers has selected GOES to serve as a communications link for the acquisition of hydrometeorological data (1). The proposed Data Collection System (DCS) will operate utilizing a network of random reporting and self-timed data collection platforms to convey river stage, precipitation and other data to a central Command and Data Acquisition Station for processing and dissemination and also to other Ground Receiving Stations. This effort is directed at enhancing existing flood control and flood forecasting services and at supplementing the hydrometeorological data base.

The GOES DCS consists of a set of remote transmitters, satellites, ground receive stations and data processing and dissemination equipment (1). This system is supported and regulated by NOAA as an integral part of its environmental monitoring capability. A brief description of the system is presented below.

1.1 GOES Data Collection System

Currently three geostationary, meteorological satellites are in equatorial orbit at an altitude of approximately 35,600 km (2) over the American Continents and adjacent oceanic areas. These were developed under the Synchronous Meteorological Satellite (SMS) Program, and are operated by NESS.

The satellite located at 75°W longitude is known as GOES-East and the satellite at 135°W longitude is known as GOES-West. A partially failed satellite, i.e., a satellite with no imaging or sounding capability, is located at 107°W longitude and is known as GOES-Central. GOES-Central acts as an operational standby for the DCS in the event of a failure of either GOES-East or West. During the two annual spacecraft eclipse periods, GOES-Central is also used to support DCS operations.

Figure 1.1 illustrates the current configuration and areal coverage provided by the two GOES satellites servicing the United States (2). These have been in operation for approximately 7 years (4). In addition, planning is currently underway by the World Meteorologic Organization (WMO) to implement a satellite data collection network capable of providing continuous global coverage of the earth's surface. It is anticipated that geostationary satellites will play a major role in such a network. Similar spacecraft are also supported by Japan and the European Space Agency. The USSR plans to eventually operate a similar spacecraft over the Indian Ocean to complete the round-the-world coverage.

The GOES system performs several meteorological data collection tasks. The satellites provide near continuous imaging of the earth's surface and its cloud cover through visible infrared spin scan radiometers (2). They also carry a Space Environment Monitor (SEM) to measure energetic particle flux, X-rays and the earth's magnetic field and broadcast Weather Facsimile (WEFAX) data (2). The GOES Data

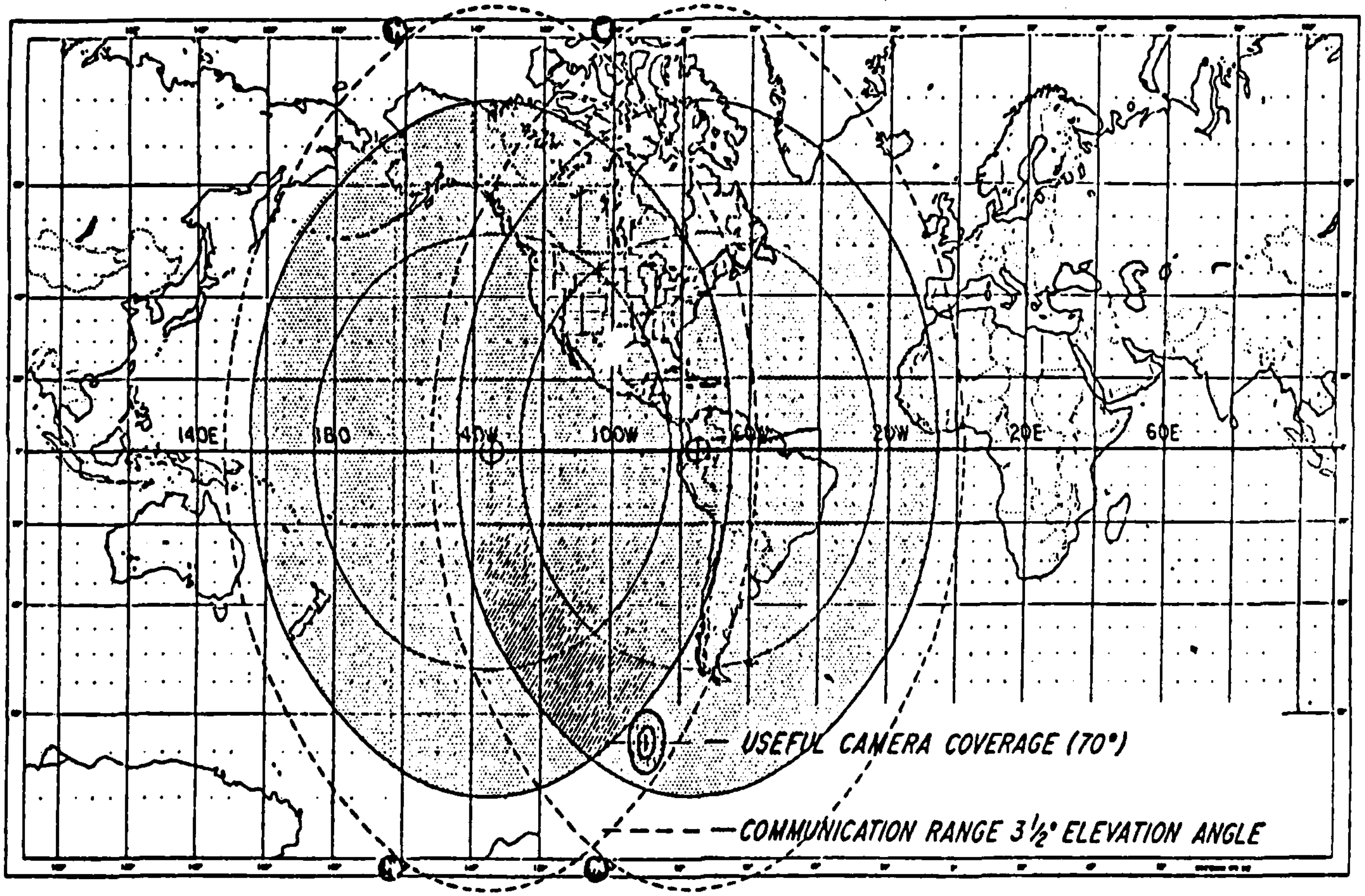


Figure 1.1: Areal coverage provided by two GOES satellites (2)

Collection System also serves as a communication link, illustrated by Figure 1.2, for the collection of environmental data. Observations and measurements of the physical, chemical or biological properties of the oceans, rivers, lakes, solid earth and atmosphere are relayed through the satellite system.

The GOES data collection system can relay messages from environmental instrumentation installed on spacecraft, ships, buoys, weather balloons, and land-based platforms. The system utilizes transmission frequencies above 400 MHz to minimize ionospheric interference (5). As shown on Figure 1.2, two sets of uplink and downlink frequencies are employed, the first at 2034.9 MHz (uplink) and 1694.5 MHz (downlink) for communications between spacecraft and large receiver systems and the second at 401.8 MHz (uplink) and 468.8 MHz (downlink) is used for communications with remote low power transmitters (4). The 401.8 MHz uplink capacity is divided into 200, 1.5 KHz, channels in the domestic or regional frequency band and 33, 3KHz channels in the international frequency band which permit low data rate, low power, remote communication (4).

The primary ground receive station for the GOES data collection network is located at Wallops Station, Virginia. Major components of this facility include:

- several receiving systems with parabolic dish antennas, ranging in size from 24 to 60 feet diameter.
- multiplexers capable of supporting up to 80 separate channels and an automatic Monitoring System.

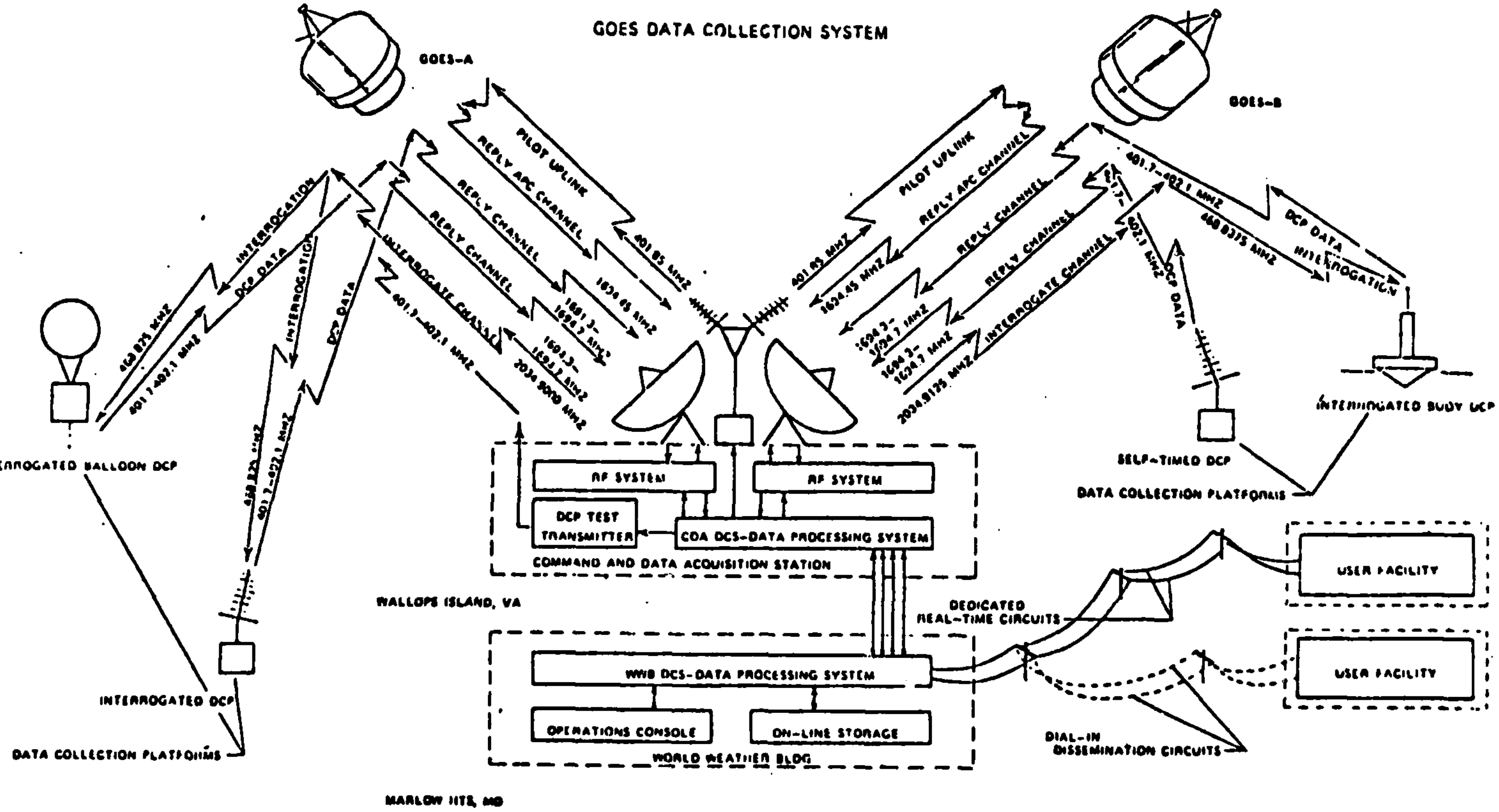


Figure 1.2: The NESS GOES data collection system (2).

- a redundant disk-supported computer system that acquires and forwards received data to the World Weather Building in Maryland. Up to 16 hours of data may be stored in the event of World Weather Building System failure,
- triply redundant lines to the World Weather Building,
- uninterruptable power sources,
- a system by which each channel is tested at least once per day using a test transmitter,
- The World Weather Building Facility contains the scheduling and dissemination computer system which allows up to 24 hours of data storage and dissemination via direct or dial-in telephone at 110/300, 1200, 2400 and 4800 baud.

Several user specific, smaller installations are also in operation. In general, these installations contain a single parabolic dish antenna and receiver to collect selected GOES signals. Data management tasks are handled by mini-computers or micro-processors.

Data collection platforms (DCP's) comprise an assemblage of electronic equipment for sensing physical conditions, formatting messages, and transmitting these over an assigned channel. These platforms are commercially available through several manufacturers providing users with a variety of sensors and data telemetry capabilities. The GOES system currently allows three primary reporting modes: 1) self timed, 2) interrogated, and, 3) random (6).

In self-timed mode users may transmit during assigned time intervals or slots of the order of one minute duration (6). Transmission intervals are controlled by precise timers within each DCP, which minimize the possibility of transmission collisions resulting in lost or erroneous data. In general, this allows each platform to transmit every few hours. Although this mode of operation simplifies data management tasks, only a limited number of platforms may share a single channel. Furthermore, since the precise time and order in which the self-timed DCP's report is predetermined, no user flexibility is afforded by the system to adapt in real time to changing environmental conditions (6).

Interrogated DCP's are designed to transmit in response to signals generated at the Command and Data Acquisition station and relayed through GOES to the network (see Figure 1.2). Each platform is assigned a unique address which is carried over an interrogation channel continuously monitored by all DCP's of this type. Upon receiving its address, the polled DCP transmits its message on an assigned reply channel. This transmission mode allows for greater user flexibility than does the self timed mode and high channel use efficiency while maintaining a comparable or better success rate for each transmission (6). In addition, the interrogated system has an event generated alert system which can be triggered by a measurement parameter exceeding a pre-set threshold. When this is received in the NESS ground system and, within approximately 60 seconds, the DCP is interrogated and the special information is transmitted via the normal reply channel. Also, special interrogation schedules can be implemented as a result of receipt of these alert messages. Increased flexibility is afforded with regard to network size and reporting frequency. Networks are limited only by address length and message duration. This capability, however, is achieved at the expense of installing high performance receivers at each platform. This receiver significantly impacts DCP complexity, power consumption and, therefore, total costs (6). Furthermore, a more complex data management and analysis procedure is required.

A variant of the self timed and interrogated transmission modes is also available which utilizes a satellite controlled timing mechanism.

Under this mode of operation, termed self timed with satellite controlled clock, an interrogation address code is multiplexed with a National Bureau of Standards time code permitting each DCP to more accurately determine the precise time of day (6). In self timed operation, this feature allows for a reduction in the required duration of time slots, which can approach that of the actual transmission duration, thereby increasing potential channel throughput. However, this mode also requires high performance receivers coupled with intelligent clock controllers at each platform (6). Therefore, a similar set of disadvantages exist.

The most recently developed mode of data telemetry available to GOES DCS users is random reporting. One principal advantage is that no requirement exists for timing of transmissions (6). This eliminates the need for precise synchronization of timing instruments in DCP networks. Another advantage is that transmissions may be initiated as a reaction to changing external environmental conditions. Further, some platforms can be programmed to transmit at rates dependent on environmental conditions. This capability, termed adaptive random reporting, is extremely valuable to users where the timeliness of information is critical to the decision making process. In essence, with random reporting, data transmission timing and frequency can be influenced largely by the users measurement requirements. A third advantage is that random reporting, obviates expensive receivers at platforms.

Random reporting DCP's must share channels' limited transmission capabilities. Since each platform on a channel transmits without regard to transmissions from other DCP's sharing the same channel, there exists the possibility of lost data due to message collisions. Moreover, data management tasks at the receiving station are somewhat more complex, inasmuch as message arrival times are not predictable.

1.2 Problem Statement

High demand exists for the development and implementation of real time, adaptive, random reporting data networks (8). As will be shown in the following chapter, there are, in fact, many systems already in operation, each with definite plans for expansion. Several of these present and future users are participating in a NESS sponsored experiment to characterize the actual operational characteristics of the random reporting systems.

Guidelines have been developed to help in the design of random reporting DCP networks (6). They assume that fixed reporting rates for all stations are known. Given those assumptions the guidelines (see Chapter 3) provide relationships between probability of message reception, number of DCP's in the system and average reporting rate at the time interval of analysis.

The Corps of Engineers and its New England Division have realized that in practice the above guidelines are applicable to a hypothetical single user of a satellite reply channel with perfectly known reporting rates. In reality, in the near future, many users (e.g., Corps Districts) in different geographical regions will be sharing one of the few allotted satellite channels for random reporting. Presently, there are only three channels on each of the East and West satellites allotted to random reporting. Since each station in each geographical region is affected by different climatic conditions, the actual average reporting rate of each region varies for different instances and is different for every user. In fact, reporting rates are a random, climatically driven condition. Given this setting it would be unnecessarily conservative to assume that all stations in the conterminous United States are reporting at their highest possible rate. Under such situations available channel would be able to handle but a fraction of the projected number of stations and users with any acceptable level of reliability of message reception. On the other hand, any single user cannot ignore in fact that his message reliability will depend on the reporting characteristics of his channel partners.

The goal of this work is then to provide a set of guidelines for the design of DCP networks that will explicitly account for geographically and climatically different users. Such guidelines will:

1) explicitly consider precipitation variability over the conterminous United States;
2) provide tools and procedures that will allow the efficient allocation of partners to a satellite reply channel;
3) satisfy NESS's rules on random reporting and the achievement of pre-specified levels of successful message transmission for each user.

CHAPTER 2

Adaptive Random Reporting: A State of the Art Review

2.1 Adaptive Behavior of Data Collection Platforms

As previously indicated, one of the main advantages of random reporting is the ability to obtain data at a rate dependent on and driven by the parameters being monitored. This is called adaptive reporting. The New England Division (NED) of the Corps of Engineers (C of E) specified the design of its DCP's with a particular adaptive algorithm responding to streamflow and rainfall rates. The form of this algorithm is common among available equipment. Following is a brief discussion of the specifications NED's Data Collection Platforms which were built by Synergetics International, Inc.

The DCP's should be suited to data collection in a variety of fields, such as hydrology, meteorology, environmental quality and geology; and capable of operating in either of two modes, the conventional self timed mode, or the random reporting mode (7). In the random reporting mode, the DCP's must perform the following tasks:

1) Monitor environmental parameters by sampling at intervals which shall be user selectable from seconds to hours.
2) Calculate past time derivatives in the sampled parameters.
3) On the basis of these parameters, their past derivatives, and user selectable threshold values, calculate randomized transmission intervals.

4) Format the latest value of the sampled parameters into either ASCII or binary numbers containing integral multiples of six bits. Twelve-bit binary words will be sufficiently large for the applications presently being planned; however, the number of six-bit multiples in each parameter must be user-selectable. Codes other than binary and ASCII must be attainable by future software modifications.

5) Transmit the coded data in a sequence of n standard GOES random messages, where n may be 1, 2, 3, up to approximately 10. The number of messages (n) must be user selectable and is variable so as to permit user manipulations which can maximize probability of reception of certain emergency data. (7)

The message format for random transmissions will have the following format (7).

Message Sub-Section	Message Length (sec)	Contents
Clear Carrier	.5	--
Clock	.48	48 alternating 1's and 0's
Maximal Length Sequence	.15	100010011010111
BCH Identifier	.31	31 bit DCP identification number
Header	.08	Set by users
Data	.48 (nominal)	8-bit/byte GOES ASCII
EOT	.08	ASCII EOT, 00000100

The proposed algorithm which a DCP must use for calculating transmission rate must be equivalent to:

RATE = MAX[BASE RATE, (A*CHANGE IN PARAMETER)] (1)

i.e., the rate is the larger of these two expressions: a user selected BASE RATE; or the product of a slope factor "A" times the absolute value of the change in parameter value, for NED this parameter is river stage (1). Depending upon the current stage, the BASE RATE will be one of three pre-selected values corresponding to low flow, alert, and flood conditions. The slope factor "A" will serve to control transmission rate during periods in which conditions are changing rapidly. In addition, a DCP may not change from short transmission intervals to longer intervals until it has transmitted a set number of times at the shorter interval. This capability is termed "momentum" (1). The base rate and the slope fraction will allow tailoring of transmission rates to local conditions.

Alternative reporting algorithms have been developed. Most commercially available DCP's also operate in an adaptive random mode based upon input from multiple sensors with the following algorithm:

RATE = BASE RATE + (A* CHANGE IN PARAMETER) (2)

As in the previous algorithm, BASE RATE can generally have three values corresponding to low, alert and warning levels. These may be selected for one or more individual sensor inputs. Commonly, three values of "A", the slope factor, are also permitted. Furthermore, parameter groups specifying the data transmitted from multiple sensors based upon a single driving parameter are user selected in some equipment. Although these capabilities could improve the data collection potential from a single DCP, network performance characteristics would not be identical to those governed by the NED algorithm.

2.2 Existing Data Collection Platform Capabilities

In order to devise a useful and relevant analysis of the performance characteristics of networks of random reporting data collection platforms, it is first necessary to understand the characteristics of these devices, and the manner in which they are likely to be employed. This information provides a basis for structuring models of network performance.

Currently, there are several companies which manufacture satellite linked data collection platforms capable of "random" reporting. Some of them are:

- LaBarge Electronics
- Handar, Inc.
- Synergetics, Inc.
- Sutron Corporation
- Magnavox
- American Electronic Laboratories, Inc.

The first four companies' device(s) were contacted. Their capabilities are discussed in the paragraphs that follow.

LaBarge manufactures two different platform models, the convertible DCP (CDCP) and the Advanced DCP (ADCP). The CDCP has 8 analog and 4 digital sensor capacity while the ADCP has 12 analog and 8 digital sensor capacity. Both are capable of transmitting "emergency" information on a secondary channel. A single parameter is monitored until the rate of change of the parameter, or its level, exceeds a prespecified threshold. Once this occurs, the platform begins transmitting at a fixed rate on the emergency channel. It is important to note that randomness is introduced only by the variable starting time of emergency channel transmissions. Once activated the emergency channel transmits at a pre-determined rate.

Handar currently manufactures two platforms capable of random reporting. Once device is an adaptation of their Model 524, the so-called 524/B. This microprocessor based system can be configured to accept up to 8 analog and 4 digital inputs. It operates in a manner similar to the LaBarge platforms. Once a specified parameter exceeds a preset rate of change or level, the platform can be programmed to begin transmitting on the secondary channel. The transmission rate is equal to the sensor scan rate -- Handar has the added capability of repeating messages up to 3 times for transmissions made on this secondary channel. Like the LaBarge unit, once the threshold event has occurred, the unit transmits at a fixed rate. Thus the only randomness is that introduced by the triggering event. If the unit is programmed to operate in both self timed and random mode, Handar labels this "random reporting"; and if the unit is programmed to operate only on the random channel, Handar labels this "random adaptive reporting". Handar calls a self-timed or slotted reporting regime, using a short message format, "self-timed emergency reporting".

The second Handar data collection platform capable of random reporting is their recently introduced Model 560 Multiple Data Access Hydrological System. This system can accept up to 18 separate analog and 12 digital inputs. Handar uses signal conditioning cards to interface with a variety of sensors. The unit is capable of preprocessing observed data computing such statistics as mean, variance, minima, maxima, histograms, rates of change, differences between sensor observations, and scaling of data. In addition to self timed modes of operation, Handar says that their instrument is capable of alert reporting (random or fixed time offset), random reporting, and random adaptive reporting. They claim that their platform is configured to randomly report exactly in the manner specified by the NESS random reporting Users Guide [6]. It appears that the random reporting mode may be triggered independently by any of the sensors. Each sensor has an alert level, a warning level, and a slope factor which can be programmed. The platform has a single base, alert, and warning rate assigned. It is not clear whether each sensor channel can initiate random reporting independently, or whether the platform rate is determined by the highest specified sensor rate, nor is it clear as to how the reporting time is randomized.

Synergetics is the most recent entrant into the field of random data collection platform development with their 3400 Series Hydrological Data Collection Platform system. This system is a modular, microprocessor based system which includes a master control module, a GOES transmitter module, a power supply, and a hydrological sensor interface module. The hydrological sensor module is configured to handle 8 analog signals, 4 digital sensors, 1 up/down counter, and 1 up counter channel. Reportedly, a single platform could handle 10 to 15 hydrologic sensor modules, with 14 channels each. In addition, the master control module has 14 internal channels which monitor the system state, and which can also be transmitted. Synergetics is currently also developing a meteorological sensor interface module. They have stated that other signal conditioning modules will be developed in the future.

For each channel selected to be adaptive, the user typically inputs 3 rates, 2 breakpoints, and 1 slope factor. Each time the sensors are scanned, the reporting rates for the adaptive channels are calculated as the maximum of the rate of parameter change multiplied by the slope factor, and the base reporting rate for the range of interest. There is a single platform reporting rate, which is selected as the maximum of the calculated reporting rates for all of the adaptive channels. Once the platform reporting rate is determined, say once every t seconds, a random number is drawn from a uniform distribution with limits 0 to 2t, which is the selected distribution on random reporting interval. The random interval is added to the time of last transmission. If the current clock time is greater than or equal to this calculated time of next transmission, then the platform immediately reports. If the calculated time of transmission is after the current clock time, but before the next scheduled sensor scan, then the unit will program itself to scan the sensors and report at the calculated transmission time. Finally, if the calculated reporting time is after the next scheduled sensor scan, then no random report will be initiated, but instead a new calculated reporting time will be computed at the time the sensors are next scanned. Additionally, Synergetics introduces a concept of momentum -- which is simply the requirement that the mean of the distribution on random reporting interval not decrease faster than some predetermined rate.

Several points are noteworthy concerning the Synergetics strategy. First, the reporting times are explicitly randomized -- however, there is a tendency for the unit to report at times coincident with the scan interval, namely when the calculated reporting time is less than the current time. Second, depending on the way the user programs the platform, a variety of sensors may be controlling the platform reporting rate -- in a relatively difficult to predict manner. Thirdly, as a microprocessor based platform, there is a great deal of flexibility that can be programmed into the hardware. Simply changing PROM's with new instruction sets can in the future radically alter the manner in which these given hardware devices will perform. This is true for all brands.

The final data collection manufacturer identified as producing a platform capable of random reporting is the Sutron Corporation who manufactures the Model 8004B. This, like the Synergetics and possibly

Handar platforms, is a powerful microprocessor based system. The microprocessor firmware controls the platform's reporting in self timed and/or adaptive random modes on two separate frequencies. A total of 16 sensors may be monitored, in any combination of analog and digital signals. Each of these monitored parameters may be assigned to one of four groups. Each group is scanned independently at preprogrammed times; and depending on available memory and groupings, up to 180 samples may be stored for the parameters in the group. One of the parameters assigned to each group is used to control the adaptive reports. Two threshhold levels, and three base reporting rates and slopes are defined for that parameter. Each time the sensors in the group are scanned, a new mean adaptive reporting rate is calculated as the sum of the rate of parameter change multiplied by the slope factor, and the base reporting rate for the interval of interest (as an option, Sutron offers to compute reporting rate as the maximum of the rate of change multiplied by the slope factor and the base rate for the interval, probably involving a minor firmware modification). Thus, there is a separate mean adaptive reporting rate for each of up to four groups. Once the group's reporting rate is determined, say once every "t" seconds, a random number is drawn from a uniform distribution with limits 0.5t to 1.5t, which is the selected distribution on random reporting interval. Note that there are time periods when (it can be shown) that the platform will not report. Note also that with each group reporting independently, the platform would behave like four separate platforms. Thus a user configuring a platform with two sensors in a single group is imposing potentially significantly less burden on the satellite system than a configuration having the sensors in two separate groups.

Sutron has the greatest experience in manufacture of random reporting data collection platforms and has pioneered much of the work in the area. In addition, they have made research contributions with studies for the New England Division, Corps of Engineers, and with participation in writing the NESS Users Guide to Random Reporting (6).

In summary, there are significant differences in the manner in which the several equipment manufacturers have translated the theory of random reporting to practical application. The LaBarge and Handar 524/B platforms are not explicitly random -- "randomness" is introduced only by the manner in which they scan their sensors, and the attainment of threshhold levels triggering reporting at a fixed rate. The Synergetics and Sutron platforms, and possibly the Handar Model 560/B, explicitly randomize their reporting times. The manner in which they specify the distributions on random reporting interval, and incorporate corollary concepts such as momentum, suggests that individual platforms quite likely violate the NESS Random Reporting Certification Standard requirement that reporting times "shall be uniformly random within the reporting interval." The extent to which this leads to violation of the Poisson arrivals assumption for networks of platform message arrivals at the satellite remains to be examined. Furthermore, platform manufacturers have taken a variety of approaches to the manner in which sensors are scanned, grouped, and sensed parameters used to control the rate(s) at which the platform reports. Careful assumptions about the manner in which rates are determined, and perhaps limitations on allowable regimes, must be developed for any meaningful analysis of network performance. Finally, and in a related vein, it must be recognized that the state of the art platforms are relatively powerful microprocessor computers -- and can be configured, programmed, and operated in relatively complex ways which are difficult to predict. Two basic strategies are possible for developing good models for predicton of performance of networks of such units. First, one might endeavor to build relatively elaborate "simulation" models to capture the complexity. This would be very costly and impractical in that it requires the analyst to forecast the complex configurations that are possible. Alternatively, the analyst might develop simplified analytic models. Great care must be taken, in this case, to insure that the actual systems implemented are constrained so as not to grossly violate the assumptions used in predictive models for network performance.

2.3 Random Reporting System Users

A number of government user groups are currently using or are likely in the near future to begin using adaptive random reporting. These include:

- -- Army Corps of Engineers;
- -- Geological Survey
- -- Bureau of Reclamation;
- -- National Weather Service;
- -- Soil Conservation Service;
- -- Bureau of Land Management;
- -- Forest Service;
- -- Tennessee Valley Authority.

These users are distinguished by factors including the numbers of platforms, types of platforms, monitored parameters, grouping of reported parameters, algorithms for reporting rate determination, and reception capabilities. A number of current or candidate user group programs are described below.

Perhaps the most advanced user is the Bureau of Reclamation in Boise, Idaho. This group started installing platforms in July, 1980. The system is a turnkey installation developed by Sutron. Currently, 66 platforms are operational, as is a ground receive station. Roughly 12 platforms are at reservoirs, and measure parameters including forebay elevation, stream elevation, precipitation, and discharge. Another 12 platforms are purely meteorologic stations, measuring parameters including precipitation, temperature, soil moisture, and water content of snowpack. The remaining platforms are at stream gaging stations, and primarily monitor stream levels and total precipitation.

The platforms in use are the Sutron Model 8004B, described in the previous section. All are configured to report on both a self-timed and a random channel. On the self timed channel, each reports every 3 hours. Parameters are scanned every 15 minutes. The random reporting algorithm varies, depending on the platform. Up to three group assignments are used -- thus the effective number of platforms is larger than the 66 units in the field. Relatively little effort has been expended attempting to forecast channel performance, as the Bureau has a fully dedicated channel, so there has been no worry about adverse affects on other users.

This solo operation is currently being changed. The Bureau is in the process of switching to Channel 128, which it will share with the Corps, Missouri River Division, and the Bureau of Reclamation, Amarillo, Texas. The Boise group anticipates addition of another 40 platforms on the Snake River within a year; also an additional 20-25 platforms in the Deschute River Basin. The Bureau in Boise has done little <u>ex post facto</u> study of its network performance. They do report, however, that during one flood event in the spring of 1981, 40 of the 66 platforms became active in a random reporting mode, and they were receiving upwards of 2200 successful random reports per day.

A second group which is currently using random reporting is the Corps, Missouri River Division. A total of 216 sites have been designated for satellite data collection. The Omaha District within the division currently has 8 operational, and 28 nearly operational platforms (as of January, 1981). The Kansas City District has 6 platforms operational. Ultimately, the Omaha District will have 110 platforms (30 additional in FY 82, another 26 in FY 83, and a final 18 in FY 84). Most of these platforms will report both precipitation and stage. Currently, using the Sutron platforms, stage is the driving parameter for random reports, and both parameters are reported in a single group. Ultimately, the Kansas City District will have 106 platforms (50 additional in FY 83, another 25 in FY 84, and a final 25 in FY 85). The Missouri River Division is participating in the NESS random reporting experiment, sharing Channel 128 with the USBR Boise. They have a Memorandum of Understanding with the Bureau that enables them to use the Bureau's ground station until 1984.

A third group which is currently using random reporting is the Corps, Tulsa. The District of the Southwest Division plan ultimately to install 132 platforms. Currently, they have 38 platforms authorized. Of these, 10 will be Handar model 524's, and the remainder will be Sutron 8004B platforms. Less than 12 of the 38 are currently operational. All 38 units will have stream and precipitation sensors. About one third of the 38 will have additional parameters, although there are no detailed specifications thus far. This office of the Corps is assigned to the eastern satellite, Channel 129, which it will share with the New England Division. Although they had not been granted final approval (as of January 1982), the Tulsa office was proposing 1.8 unit loads per platform (a definition of a unit load is given in Chapters 3 and 4) during the NESS test.

A fourth group which will begin using random reporting is the Corps of Engineers, New England Division.

The National Weather Service currently has no random reporting or interrogated platforms, although they have ordered a few for testing and evaluation. The Geological Survey is reported to have random reporting platforms, but this has not yet been verified. For NESS test purposes, the Weather Service and Geological Survey are assigned to share channels 118 and 140. According to NESS, the primary interest of these groups is transmission of an alert warning once a monitored parameter has exceeded a predetermined threshhold -- rather than the continuous real time data transmission sought by the Corps and the Bureau of Reclamation.

Groups reported to have random reporting capabilities, but which were not contacted, include the Bureau of Land Management, Denver, and the Forest Service, Boise. Groups considering developing random reporting capabilities include the Corps, Portland, District of the Northwest Division, and the Tennessee Valley Authority. They are illustrative of the scope and variety of hydrologic/meteorologic random data collection users.

CHAPTER 3

Models of Data Collection Platform Network Communication

3.1 Overview

The purpose of this chapter is to review and assess relevant models which might be used in the analysis of networks of random data collection platforms. It is essential to keep in mind the obvious -- that the problem is simply one of analyzing communications. These communications are between distributed users and a central site. The fact that the senders are microprocessor controlled data collection platforms, that the transmission link is a satellite, and that received information is computer routed, should not disguise the simplicity of the underlying problem.

3.2 Network Communication Strategies

Consider a network like that shown in Figure 3.1. In the most general case, each node can function to generate, receive, store, or route transmissions. Links can be used to transmit in both directions. Historically, two modes of network communications have been distinguished:

1) circuit switched (pre-allocation)

2) packet switched (dynamic allocation)

Communicating implies transfer of information between selected origin-destination pairs, as opposed to broadcasting, which would suggest transmission between an origin and all possible destinations on the network. Each of the two modes is described below.

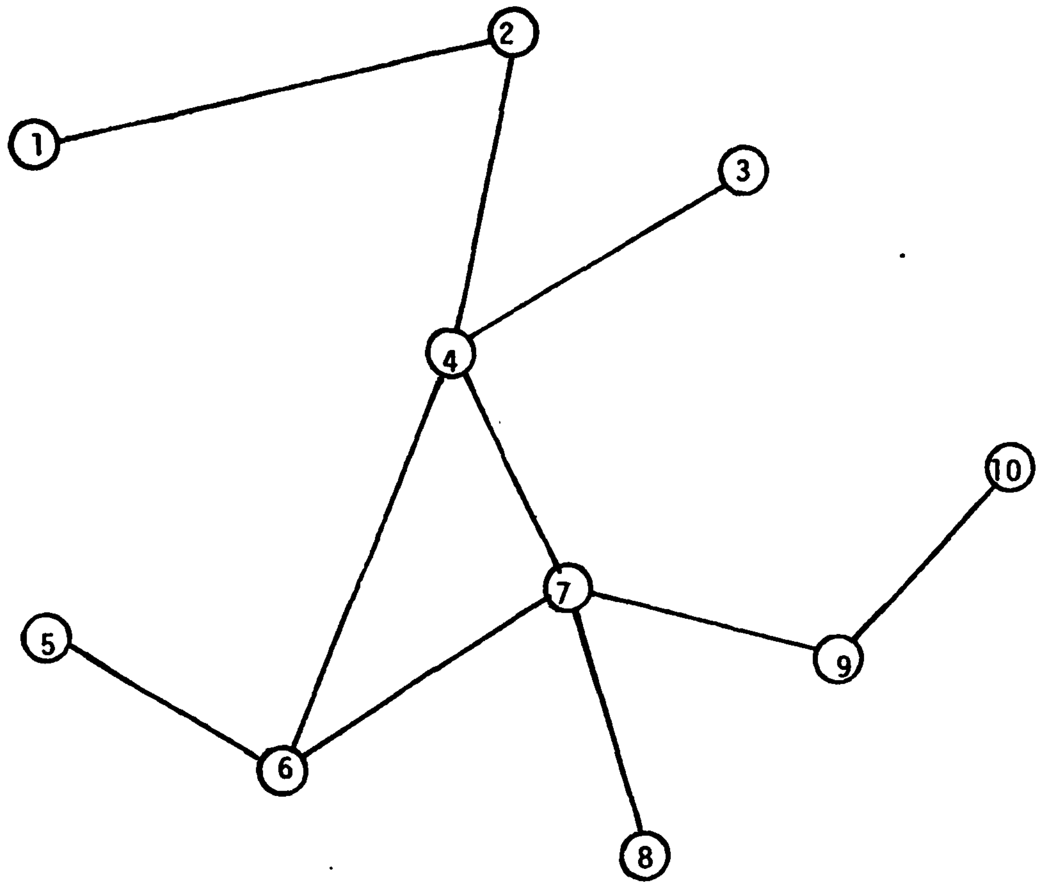


Figure 3.1: Sample Network

In the circuit switched pre-allocation mode, the path from sender to receiver is established in advance, before communicating commences. Once established, this path or circuit is maintained. In order to efficiently use network capacity, this scheme requires a relatively strong, centralized assignment control mechanism. The advantage to users is that they face no delays in communicating their information once they have established access to a circuit. No information storage is required. The disadvantage is that because the assignment of circuits cannot readily adapt to changing demands, the network capacity may be inefficiently assigned and utilized. Traditionally, telephone, radio, and television have employed circuit switching.

In the packet switched or dynamic allocation mode, "packets" of information may be sent, stored, sorted, and ultimately routed over a path in the network to their destination. The path is not pre-assigned, but established depending on conditions in the network at the time of transmission or retransmission of data packets from nodes in the network. This format facilitates relatively decentralized communications and control. One disadvantage is that delays may be encountered as information is stored or rerouted. Further, since there may be no centralized control of access, users may not have exclusive use of circuits thereby resulting in unreliable communications. Examples of packet switched networks have included telegraph and mail systems. Computers have made possible high speed packet switched communications, by greatly enhancing the capacity to store, sort, and route information in near real-time. Computer controlled telecommunications have made feasible dynamic allocation systems that in some aspects are superior to preallocation systems in time, reliability, economy, and flexibility (9).

3.3 Multiple Access Protocols

When a multiplicity of users can have access to a shared link or path in a communication network, rules may be established to reduce or eliminate conflicts between users. The parameters for dividing access include time, frequency, and encoding. According to Lam (14), multiple access protocols have traditionally been channel oriented. That is, the network is divided into separate channels, and channels assigned on a fixed or demand basis.

Three distinct protocol classes may be used to control channel acccess:

1) reservation;
2) polling; and
3) contention

Each class is described below.

The reservation protocol seeks to eliminate conflicts between users. If reservations are static, then users can communicate only at specified times, on specified frequencies, or using selected codes.

If reservations are to reflect user requirements in a dynamic sense, then two issues must be resolved. First, a channel must be established for users to communicate their requirements for a reservation. Second, a queue of user reservations must be maintained, on a centralized or distributed basis. Note that in order to implement adaptive reservation systems, users must be able to both send and receive -- communications must be bidirectional.

A polled or interrogated protocol also will eliminate conflicts between users. Users are given access to a channel only when interrogated by a central controller. There is again the requirement that users have the ability both to send and receive signals. Generally, depending on the sophistication of the central controller, this protocol provides a fairly efficient mechanism for data acquisition. However, as is the case with satellite linked communication, when there are relatively long propagation times for communicating, the overhead imposed by interrogation of users can become significant. Note that in a pure polling system, users do not have the opportunity to communicate events unless polled.

A contention protocol does not seek to eliminate all conflicts between users. Each user independently chooses when to transmit, without regard to other users who may be transmitting at the same point in time. This protocol was first implemented in a computer communications network, the ALOHA system, at the University of Hawaii in

1970 (14, 10, 11, 13, 15). Under the unslotted ALOHA protocol transmissions are unsynchronized over a common channel. A slotted ALOHA protocol simply restricts times at which transmissions can be initiated, but otherwise does not restrict user access. Both the ALOHA and the slotted ALOHA protocols were developed assuming users could receive, thereby getting immediate feedback on the success or failure of their attempt to access the communication channel. The protocol is feasible without feedback, but in this case, lost transmissions must be accepted or data repetition methods devised to insure reception. The R-ALOHA protocol is a variation in which time slots are organized into groups called frames, and availability of a particular slot depends upon the status of the corresponding slot in the previous time frame. The R-ALOHA system clearly requires bidirectional communications. A similar hybrid contention model known as the URN protocol, which is adaptive, also needs feedback. Note that the contention protocols can circumvent central control and are completely user initiated.

3.4 Framework for GOES DCS Analysis

The GOES system as a packet switched system, in which frequency bands have been subdivided into channels, is well suited to networks of distributed users communicating with static centralized control. This sort of communications is made practical by the ability of microprocessor and computer's capabilities to quantify, transmit and store, information at high speed.

When multiple users have access to a single network, access may be divided in time, frequency, or encoded information. The GOES system uses discrete channels. Conflicts in time on a single channel are avoided by one of the three types of multiple access protocols:

1. reservation (self timed)
2. polling (interrogated)
3. contention (random access).

NESS has elected to test all three types of protocols. Only the random access protocol allows the user both to report based on locally observed events and to avoid the significant expense of receiving capability.

Although a number of articles have addressed the performance of communication networks, the basic findings of Abramson (11, 12, 15) and others (13, 14, 20) are especially germane. The key to the applicability of these results in analyzing the GOES system is insuring that the system is compatible with the assumptions in which the analysis are predicated. For the GOES system, the regulations and certification standards for radio sets imposed by NESS insure that most of the asssumptions can be satisfied -- for example, transmissions of a fixed length, or uniformly random message starting time. Recall, however, that because some types of platforms might not transmit only randomly, and because users can inadvertently synchronize transmissions, NESS must carefully regulate system use to insure that key assumptions are not violated. The rate of arrival of transmissions at the satellite is an extremely important factor, and the previous assumptions have to be satisfied.

Although the literature has successfully provided models of network performance, pure contention cases in which undetected transmission failures can occur have been analyzed only in the NESS User's Guide (6). Moreover, the previous analyses, with the exception of some limited simulation studies done by Sutron Corporation for the New England Division, Corps of Engineers (4), have addressed network performance merely assuming given platform transmission rates. In reality, the platform transmission rates are a function of sensed climatic information, platform characteristics, and user selected input parameters. This transformation of sampled data to distributed reporting rates is non-trivial, and is one of the major research concerns of the current project.

Figure 3.2 presents one possible representation of the communications system of interest to the Corps of Engineers and NESS. One driving force for system performance is the climate to be sensed and reported. At the user leve', a network of platforms is installed to provide information for reconnaissance, planning, and real time control. These platforms are subject to constraints imposed by the authority

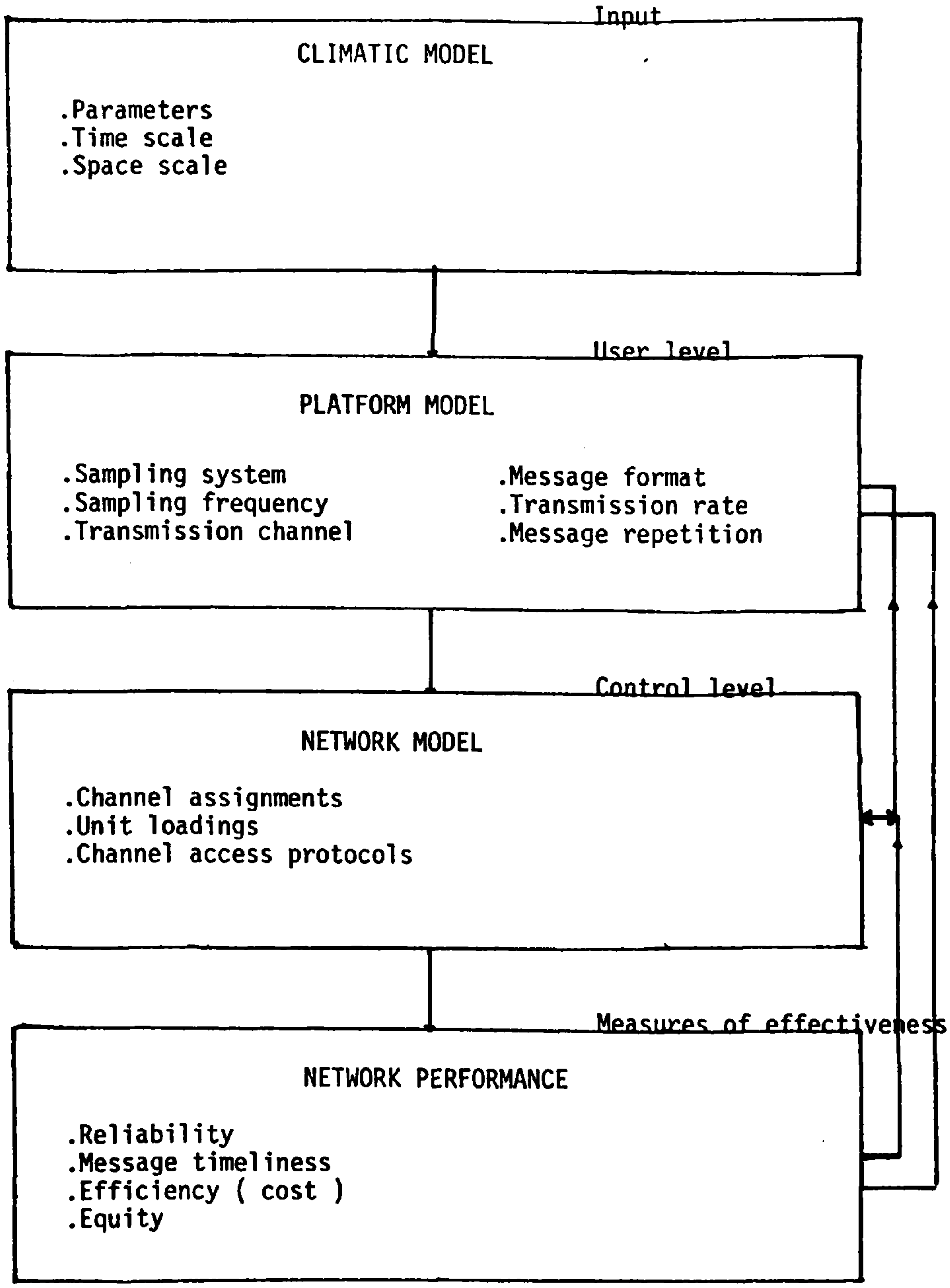


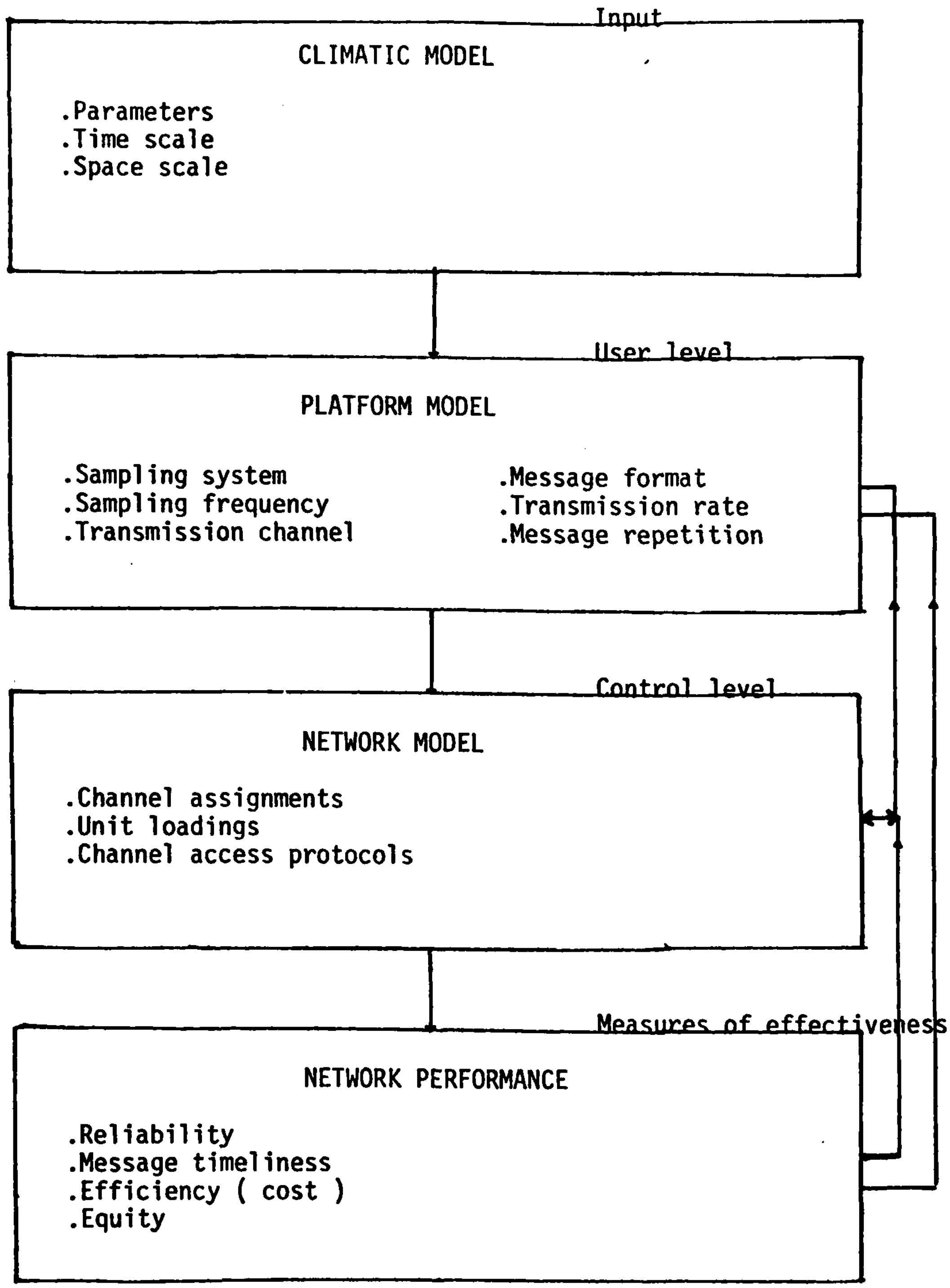
Figure 3.2: Framework for data collection system analysis

controlling the network -- for example, message formats and unit loadings. At the control level, channel access and assignments are established. A number of measures have been used to determine the performance of such a system.

These measures include but are not limited to:

* reliability -- the rate of success of that a message being received without interference;
* timeliness -- the delay from initial transmission attempt until the information is available to a user;
* efficiency -- the level of utilization of channel capacity, perhaps as measured by number of users of a particular type; and,
* equity -- fair allocation of resources among users.

Given climate, platform characteristics, and network attributes, one important goal is to forecast network performance as summarized by selected measures. Given the inputs, user, and control decisions, a descriptive model would be a simulation of network performance. A more difficult problem which will not be addressed in the current research is that of optimization of network performance. That is, finding the "best" set of user and control decisions to achieve selected network performance goals. The difficulties of optimization lie in that the above measures of performance are poor surrogates of the value of information during the ultimate use of the data.



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3.5 Models for GOES Network Performance

The GOES data collection system introduced in Chapter 1 consists of distributed data collection platforms, using a satellite communications line, to transmit sensed data to a central ground station (or stations), and ultimately to end users. A schematic of the implied communications network is shown in Figure 3.3.

The National Earth Satellite Service (NESS) has established a number of conventions which regulate the manner in which the network may be accessed. The basic strategy has been that of packet-switching or dynamic allocation. This format facilitates relatively decentralized communications and control. Part of the strategy has also been to divide the uplink band into 233 channels -- so-called frequency division multiple access. Platforms can then be assigned to separate reply channels, thereby to a certain degree eliminating multiple access conflicts, at least in the frequency domain.

Currently, NESS is using pure strategies, i.e., all platforms assigned to the same channel are subject to one of the same three protocols described in the previous section. The above NESS protocols are subsets of the reservation, polling, and contention strategies described earlier. Note that the links between user and the ground station have not been closely examined.

The reservation or self-timed approach restricts data collection platform access to predetermined time slots. Normally, the slots are of 1 minute duration, and platforms are restricted to 8 slots or minutes per day. This 8-minute time allocation per platform is a management

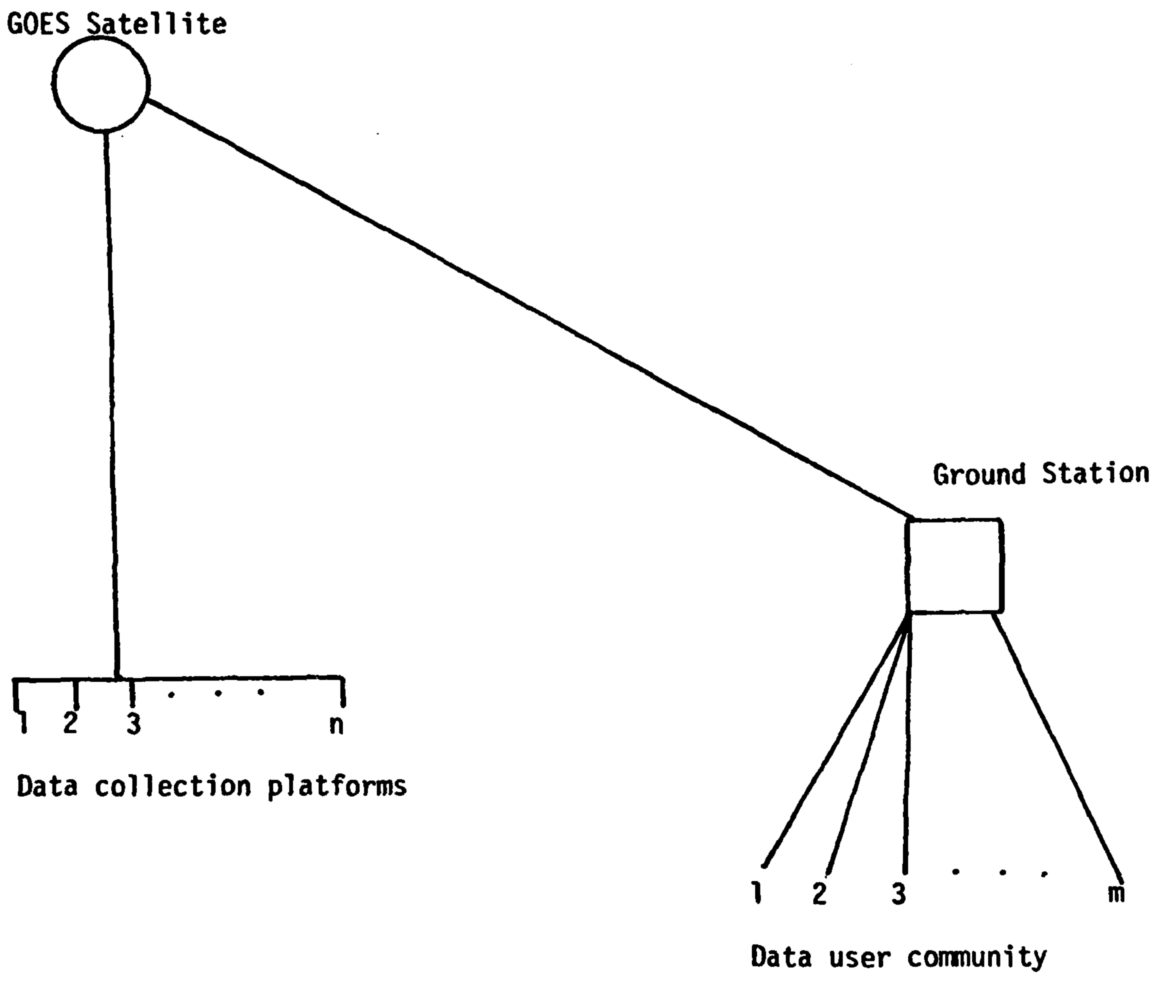

Figure 3.3: Schematic representation of GOES data collection system

concept for allocating time on channels equitably, and is known as the unit load. Typically, a self-timed platform does not have to receive signals from the satellite, provided the platform contains a sufficiently accurate clock, so that the timing of transmissions is stable. Note that the static reservation system selected is intended to eliminate conflicts -- but only 180 platforms can be assigned per channel, and there is no adaptive reporting.

The interrogated system allows the ground station to poll or query users when a report is required. One of two frequencies is employed for polling depending upon the operational satellite being used. Naturally, each data collection platform must have the ability to receive satellite signals. This can be costly, or infeasible, given the remoteness of data collection sites and the availability of reserved or random access alternatives.

The random access protocol available to GOES users allows pure contention among users for channel access. Users independently decide to transmit, subject to the constraint that the total time of transmissions per random reporting platform does not exceed the unit load. Since most random reporting platforms also transmit in a self timed mode, the 8 minute access time is further restricted to:

a. 6 minutes on a self-timed channel,

b. 2 minutes on the random access channels (average of 5 seconds per hour).

The message formats are user defined. In the NED application the standard message is approximately 3 seconds long. The time of transmissions is taken to be uniformly random.

Recall that because each platform is reporting independently, the possibility exists that a message from one platform may collide with those of other platforms sharing the same channel. Most of the analyses of ALOHA type systems (see previous section) assumed bidirectional communications, allowing users to listen and hear whether their transmission attempts were successful. Should an unsuccessful attempt be detected, the user could always retransmit. Random access users on the GOES system are not equipped to receive satellite broadcast.

Accordingly, users of the GOES system must either tolerate lost transmissions, or adjust their transmission rates to compensate for the lost transmissions. Adjustments suggested in the "Random Reporting Users Guide" (6) include message repetition which effectively increases transmission rates, or concentration of messages, leading to larger message units. These adjustments are critical to the success of a unidirectional random reporting system which requires a high level of reliability. Analysis of this type of pure contention system has largely been in relation to GOES satellite services.

The protocols described above have been developed to achieve reliable communications in a multiple-access mode by partitioning time, and are referred to as time division multiple access (TDMA). An alternative means of random access can also be obtained through frequency division, where signals are partitioned over on frequency spectrum. This is termed frequency division multiple access (FDMA). For large networks in which users (DCP's) have a high ratio of peak to average data telemetry requirements, such as that of most event based environmental measurements, the TDMA pure contention protocol provides a powerful means of sharing communications resources (10, 11, 14).

Next subsections will describe analytical performance models for the two most popular random access (contention) protocols. These are the slotted and unslotted ALOHA systems, the latter corresponding to the mode of operation selected by NED. Emphasis will be given to unslotted ALOHA's and methods to improve their performance.

3.5.1 Analysis of Unslotted ALOHA Reporting Schemes

A number of researchers have analyzed performance of contention or ALOHA type systems. Abramson (12) provided the first formal presentation of unslotted ALOHA channel performance. Work by Abramson (11, 12, 15), Lam (14, 20, 23), Kleinrock (26, 27, 28) and others (13, 16, 17, 18) has contributed to development of an understanding of random reporting. Recently, the Sutron Corporation (11) and the Water and Power Resources Services (6) have developed analyses which more comprehensively address the GOES network.

Most analyses have focussed on a critical period (peak loading) of the network. The following are assumed to be known:

N = number of platforms assigned to the channel.

λ_i = average transmission rate from platform i (transmissions/ second)

λ = average transmission rate from N platforms = $\sum_{i=1}^{N} \lambda_i$

T = duration of transmission.

The focus has been on the network of platforms on a channel -- and not the manner in which the rates are determined by user level decisions or climatic inputs.

A transmitted message can be received incorrectly or completely lost due to two different types of errors: (1) random noise errors and, (2) errors caused by message overlap (12). Most researchers have concentrated on errors of the second type and the same approach will be taken here. Accordingly, a message is lost if transmissions from one or more platforms collide as illustrated in Figure 3.4. Define D as the interval between transmissions. If a single DCP sends a message of duration T (T much smaller than D) with starting time uniformly distributed in D, and if all DCP's act independently of all others, then the probability of collision (failure) is the ratio of collision interval to D.

$$P = \frac{2T}{D} \tag{3.1}$$

where P is probability of failure and a pair of DCP's have been considered at a time.

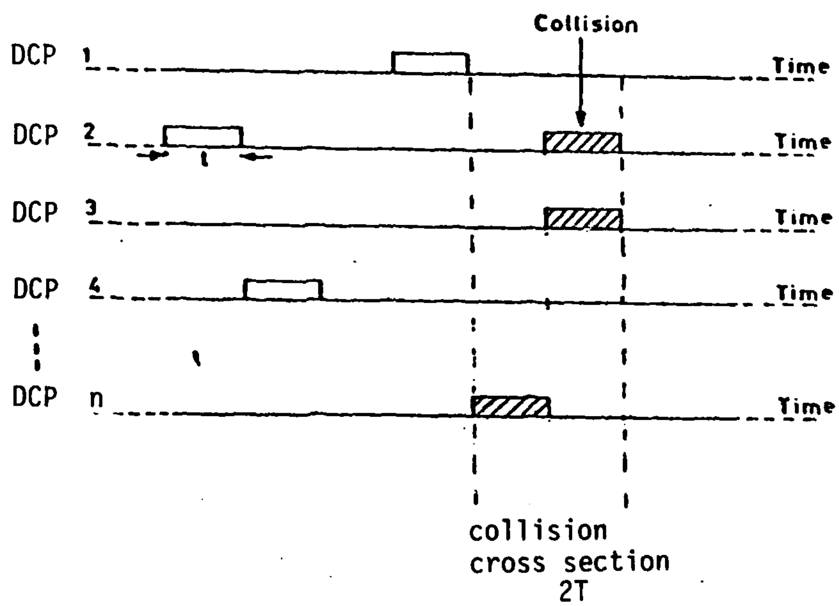

Figure 3.4: Collisions in unslotted ALOHA systems
(adapted from 10)

The complementary probability, that of the pair of transmissions <u>not colliding</u> is:

$$q = 1 - \frac{2T}{D} \qquad (3.2)$$

Equations 3.1 and 3.2 then effectively represent success and failure probabilities of a classical Bernoulli experiment (one where only 2 outcomes are possible). If there are N stations, the probability of no failures then follows the well known Bernoulli distribution. We are asking for no collisions in N (number of stations) experiments. The result, due to the independence of stations, is:

$$P_S = q^N = (1 - \frac{2T}{D})^N \qquad (3.3)$$

where P_S is the probability of no interference among the N stations or effectively the probability that any station will successfully transmit a message. The complementary probability of failure, P_f, for any station in a field of N is then,

$$P_f = 1 - (1 - \frac{2T}{D})^N \qquad (3.4)$$

The term of the form $(1 - X)^N$ in the above equation for $|X| < 1$, can be expanded in a series as,

$$(1 - X)^N = 1 - XN + \frac{X^2}{2!} N(N-1) - \frac{X^3}{3!} N(N-2)(N-2)$$

$$+ \frac{X^4}{4!} N(N-1)(N-2)(N-3) \ldots.$$

If N is large, then that series approximates the exponential form e^{-XN} since it is given by $e^{-NX} = 1 - X + \frac{X^2}{2!} N^2 - \frac{X^3}{3!} N^3 + \ldots$ For large N, Equation 3.3 then becomes:

$$P_s = e^{-\frac{2T}{D} N} \tag{3.5}$$

and

$$P_f = 1 - e^{-\frac{2T}{D} N} \tag{3.6}$$

Since in the above N is large and transmission times are random, which leads to random times between transmissions, then we can define

$$\lambda = \frac{N}{D} = \sum_{i=1}^{N} \lambda_i \tag{3.7}$$

which can be interpreted as an average rate of transmission of the network or the average rate at which the satellite receives messages. Using 3.7 the probability of successful transmission for a station in a large network is

$$P_s = e^{-2\lambda T} \tag{3.8}$$

Probabilistically, the result corresponds to the asymptotic covergence of the Binomial distribution (Equation 3.3) into the Poisson distribution (Equation 3.8). As the number of stations becomes large the arrivals of messages at the satellite becomes a Poisson process with rate λ. The probability of x arrivals at the satellite in time t is:

$$P[x] = \frac{(\lambda t)^x e^{-\lambda t}}{x!} \tag{3.9}$$

A valid question is how large N has to be to make the Poisson approximation valid. This depends on the value of $\frac{2T}{D}$. Since T is on the order of 3 seconds and D is at best on the order of 10 minutes, $\frac{2T}{D}$ *is at most on the order of 0.01. The following table illustrates the* approximation.

N	$(1-.01)^N$	$e^{-.01N}$
1	.99	.99
10	.9044	.9048
20	.8179	.8187
30	.7397	.74
200	.1340	.135

Clearly the results are extremely good over a wide range of N values. It will remain so as long as 2T/D is small.

Given the above, the discussion can be reoriented to the point of view that arrivals of messages at the satellite are in fact Poisson distributed. A corollary statement is that the time between arriving messages is exponentially distributed

$$f_D(D) = \lambda e^{-\lambda D} \tag{3.10}$$

where D is the time between messages.

In order to re-develop the analysis then make the following assumptions (6):

1. There are relatively large number of platforms assigned to the channel, $N \geq 50$ according to (6);
2. No platform uses a large amount of the available transmission time [reference (6) suggests $T\lambda_i < 0.1$];
3. The average rate of reception at the satellite, λ, is constant for the time period of interest:
4. Starting time of transmission arrivals at the satellite is statistically independent of the starting time of other transmission arrivals.
5. Transmissions are of a fixed and equal length, T.
6. Errors due to random noise are negligible, but if a transmission overlap occurs, all information is lost.

Let:

G = average number of transmissions attempted in T seconds, the channel traffic or loading

S = the average number of successful transmissions in T seconds, the throughput

P_s = the probability of success of one transmission.

Then by definition

$$G = \lambda T \qquad (3.11)$$

Also,

$$P_s = S/G \qquad (3.12)$$

That is, the probability of success is simply the average rate of success of transmissions.

Because transmission deviation for all users or platforms is assumed constant, a single transmission starting at time t will be successful if no other transmissions occur in the interval t-T to t+T (see Figure 3.4). That is

$$P_s = \text{probability}\left[\begin{array}{l|l} \text{no transmissions} & \text{transmission} \\ \text{in interval} & \text{at } t \end{array}\right]$$

where P[A|B] stands for probability of A given that B occurs. Since starting times of messages are assumed independent, the probability of no transmission at time t is also independent. Therefore

$$p_s = \text{probability} \left[\begin{array}{l} \text{no transmissions} \\ \text{in interval} \end{array} \right]$$

The likelihood of this event depends on the rates and distribution of message generation.

But from Equation 3.9 the probability of no arrivals in interval t is,

$$P[X=0] = e^{-\lambda t} \tag{3.13}$$

Accordingly, for an interval of duration 2T,

$$P_s = e^{-2\lambda T} \tag{3.14}$$

That is, the probability of success of one transmission depends only on the network transmission rate and message duration. Substituting from the definition of Equations (3.11) and (3.12), it is easily shown that

$$p_s = e^{-2G} \tag{3.15}$$

and

$$S = Ge^{-2G} \tag{3.16}$$

That is, the probability of success and the channel throughput can easily be related to the channel loading.

Figure 3.5 displays equations (3.15) and (3.16) as a function of channel loading. Observe that channel throughput is maximized at 0.184 when the overall channel loading, G, equals 0.5. At this level of loading, channel utilization <u>efficiency</u> is maximized; however, the network is relatively <u>unreliable</u>, with the probability of success of a single transmission only 0.368. Observe that P_s decreases monotonically as channel loading increases.

Figure 3.6 displays the tradeoffs between reliability and throughput, a measure of efficiency. Assuming both higher levels of reliability and throughput are preferred, all channel loadings higher than 0.5 are dominated -- there exist better alternatives at lower loading levels. The decision maker must then tradeoff high reliability for efficiency, and vice versa. The overall channel loading selected must represent a compromise between these two conflicting objectives.

If the user chooses to operate at a channel loading, G, of 0.5, then it is possible to make a statement on the maximum allowable number of stations. Remember $G = \lambda T$, where

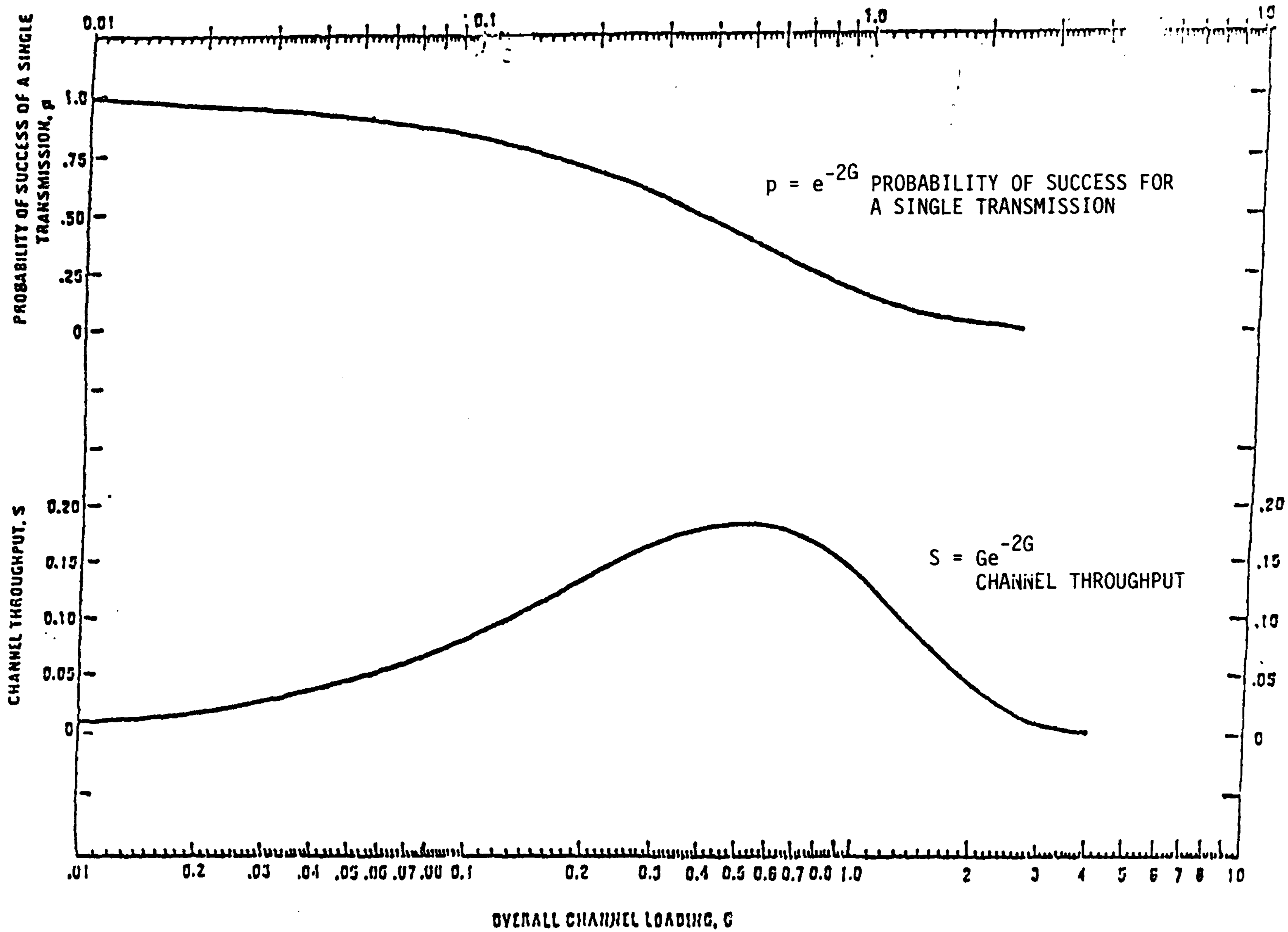

Figure 3.5:. PROBABILITY OF SINGLE TRANSMISSION ARRIVING WITHOUT INTERFERENCE AND OVERALL SUCCESSFUL TRANSMISSIONS IN TIME T (S) AS A FUNCTION OF OVERALL CHANNEL LOADING (6)

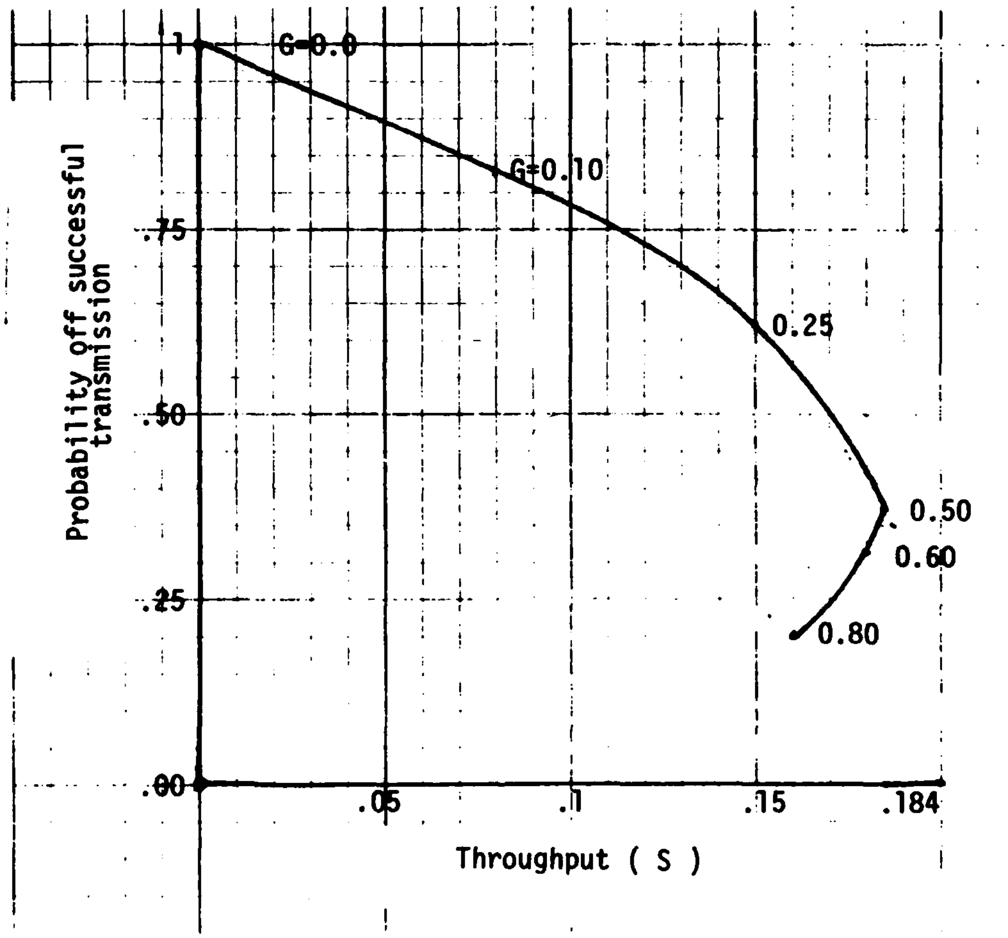

Figure 3.6: Tradeoff between reliability and efficiency

$$\lambda = \sum_{i=1}^{N} \lambda_i = N\bar{\lambda}$$

and $\bar{\lambda}$ is interpreted as an average transmission rate (transmissions per unit time) for all N stations. Then choosing G = 0.5 leads to

$$0.5 = N\bar{\lambda}T$$

or

$$N_{max} = (2\bar{\lambda}T)^{-1} \tag{3.17}$$

In the above it is <u>assumed</u> that a) $\bar{\lambda}$ is a <u>known</u>, <u>fixed</u> quantity; b) T is the same for all stations; and c) a reliability (probability of successful transmission, of only 0.368 is acceptable.

Figure 3.7 illustrates Equation 3.17 for different transmission lengths and average station reporting rates.

3.5.2 <u>An Improvement in Performance: Slotted ALOHA Systems</u>

The unslotted ALOHA system suffers from low probability of successful transmissions and low channel utilization in terms of

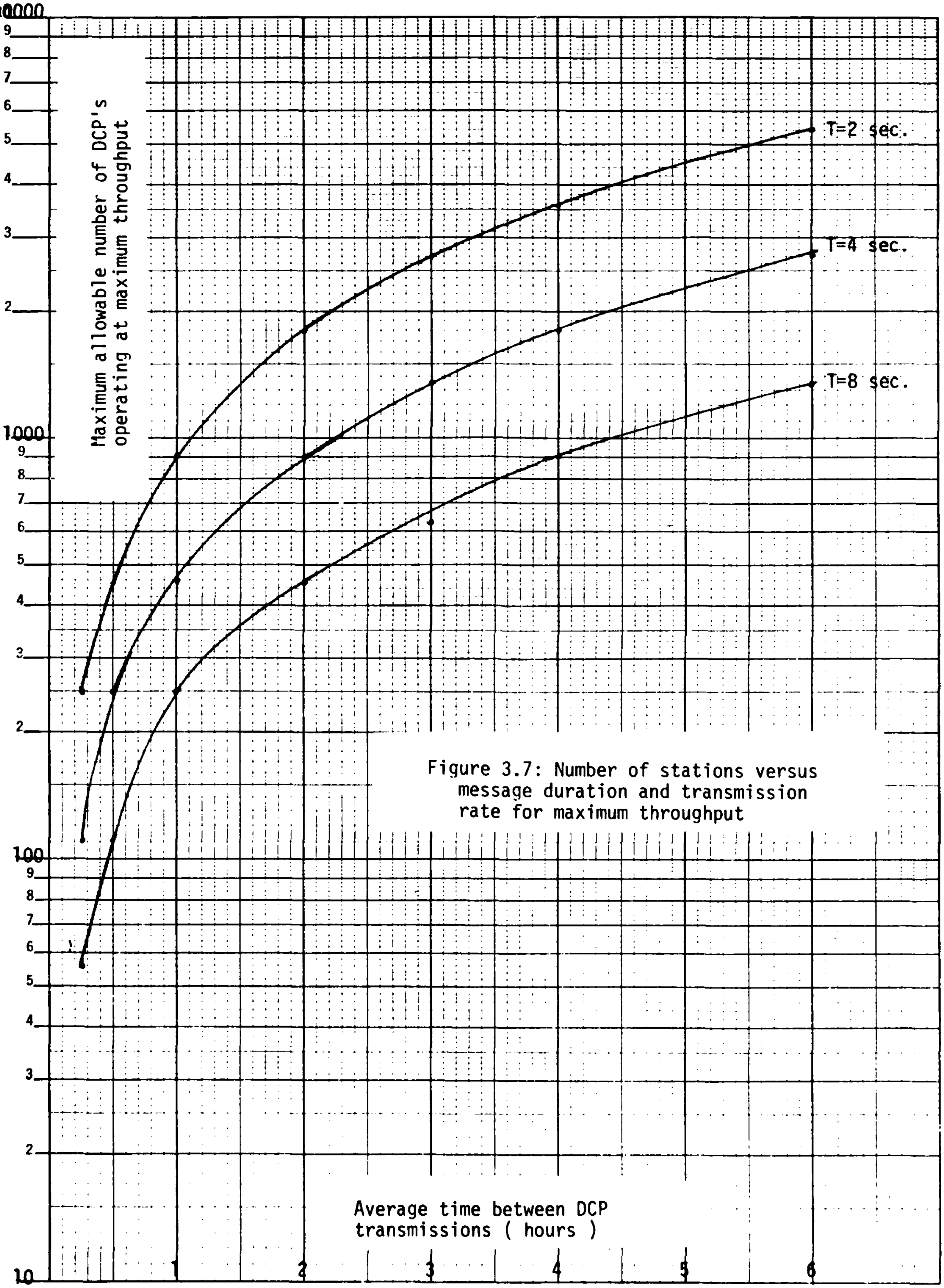

Figure 3.7: Number of stations versus message duration and transmission rate for maximum throughput

throughput. Several modifications to the system have been suggested. A popular, well studied, alternative is the slotted ALOHA system (11, 10, 12, 14b). The principle is to introduce some order into the otherwise completely random ALOHA system. The order comes by dividing time into slots of duration equal to the transmission length. DCP's are then allowed to transmit synchronously with the beginning of a slot. Otherwise, DCP's still perform independently from one another. The result of this time slotting is that failure or loss of messages occurs only by complete and exact overlap as illustrated in Figure 3.8.

Following Abramson (11), the analysis of this system follows. Define G_i as the probability that the i^{th} DCP will transmit in a particular slot. Given N independent DCP's, the total normalized traffic in the channel is

$$G = \sum_{i=1}^{N} G_i \tag{3.18}$$

Define as S_i the probability that the i^{th} DCP is the only one transmitting in a given slot, $S_i \leq G_i$. The total normalized channel throughput is then

$$S = \sum_{i=1}^{N} S_i \tag{3.19}$$

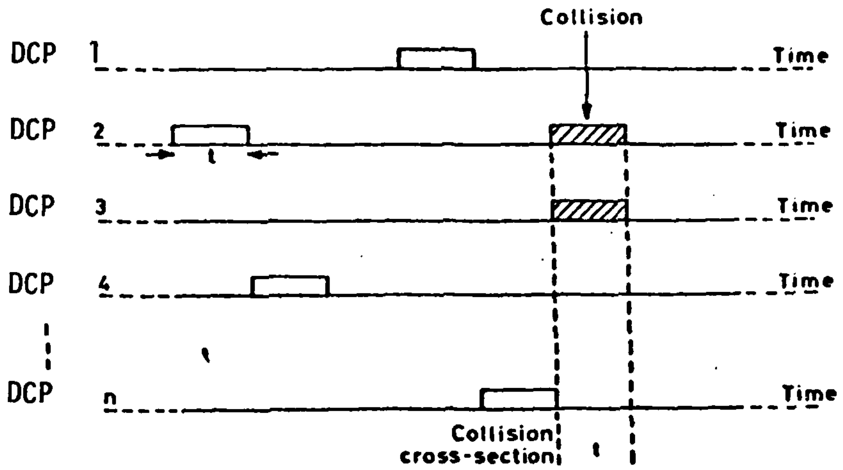

Figure 3.8: Collisions in slotted ALOHA systems (10) .

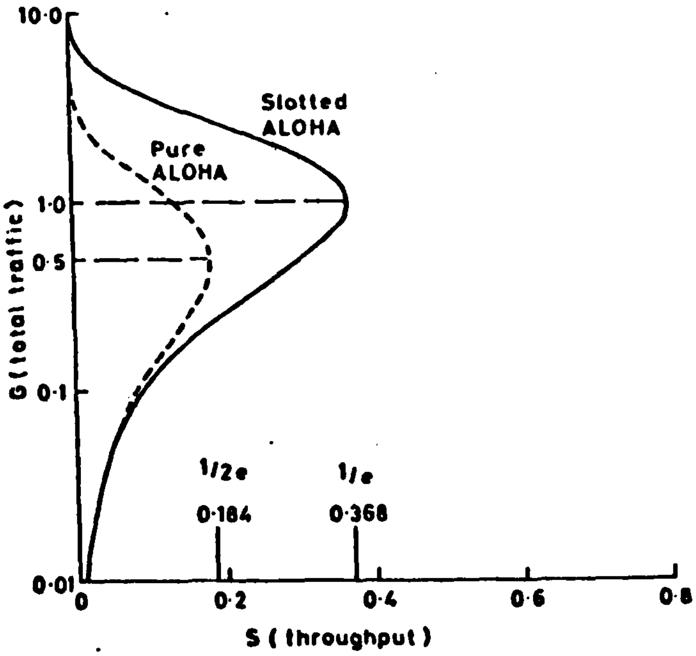

Figure 3.9: Performances of Slotted and Unslotted ALOHA systems (10)

The probability of the i^{th} DCP sending a message and successfully completing it among the N independent DCPs is

$$\prod_{\substack{j=1 \\ j \neq i}}^{N} (1 - G_j) \tag{3.20}$$

which is just the product of the probability that the other N-1 stations do not transmit in that slot.

Using the definition of S_i, it must then hold that

$$S_i = G_i \prod_{\substack{j=1 \\ j \neq i}}^{N} (1 - G_j) \tag{3.21}$$

But if all users are identical, from (3.18) and (3.19)

$$G_i = \frac{G}{N} \qquad \text{and} \qquad S_i = \frac{S}{N}$$

so 3.21 yields

$$S = G(1 - \frac{G}{N})^{N-1} \tag{3.22}$$

which as $N \rightarrow \infty$ results in

$$S = Ge^{-G} \tag{3.23}$$

Notice that if the Poisson message arrival assumption is accepted, Equation (3.23) could have been arrived at very quickly. Total throughput, S, must be total traffic times probability of successful transmissions,

$$S = GP_s$$

But according to the method of failure described in Figure 3.7, a successful transmission results from no transmissions in interval T, which from Equation 3.9 results in

$$P_s = P[0] = e^{-\lambda T} \tag{3.24}$$

where λ is the total average message arrival rate. Using the definition of total traffic as,

$$G = \lambda T$$

then (3.24) results in

$$P_s = e^{-G}$$

or $S = Ge^{-G}$ as previously obtained.

The performance of a slotted AHOHA (Equation 3.23) is compared to an unslotted (pure) ALOHA (Equation 3.16) in Figure 3.9. A maximum throughput of 0.368 is achieved at a traffic of G = 1. The probability of successful transmission remains 0.368 at this maximum throughput condition.

The difficulty of the slotted ALOHA system in terms of C of E applications is the requirement of accurate timing devices sufficiently accurate to maintain sychronization of messages and slots. This added expense is significant; the system is also more apt to destabilize and will require higher maintenance.

3.5.3. Improvements in Unslotted ALOHA Performance

NESS and C of E have essentially selected the unslotted ALOHA system as their method of random reporting. In fact, for bursty, short messages typical of environmental applications, the unslotted ALOHA, random reporting, system approaches or surpasses the efficiency, in terms of channel utilization, of operational protocols requiring more expensive and sophisticated equipment. This is acknowledged by all investigators and illustrated in Figure 3.10, which plots channel efficiency versus message length for various protocols, including random reporting with various success probabilities.

Many valuable results have been reported for random (unslotted ALOHA) reporting. Abramson (11) shows how total channel throughput can

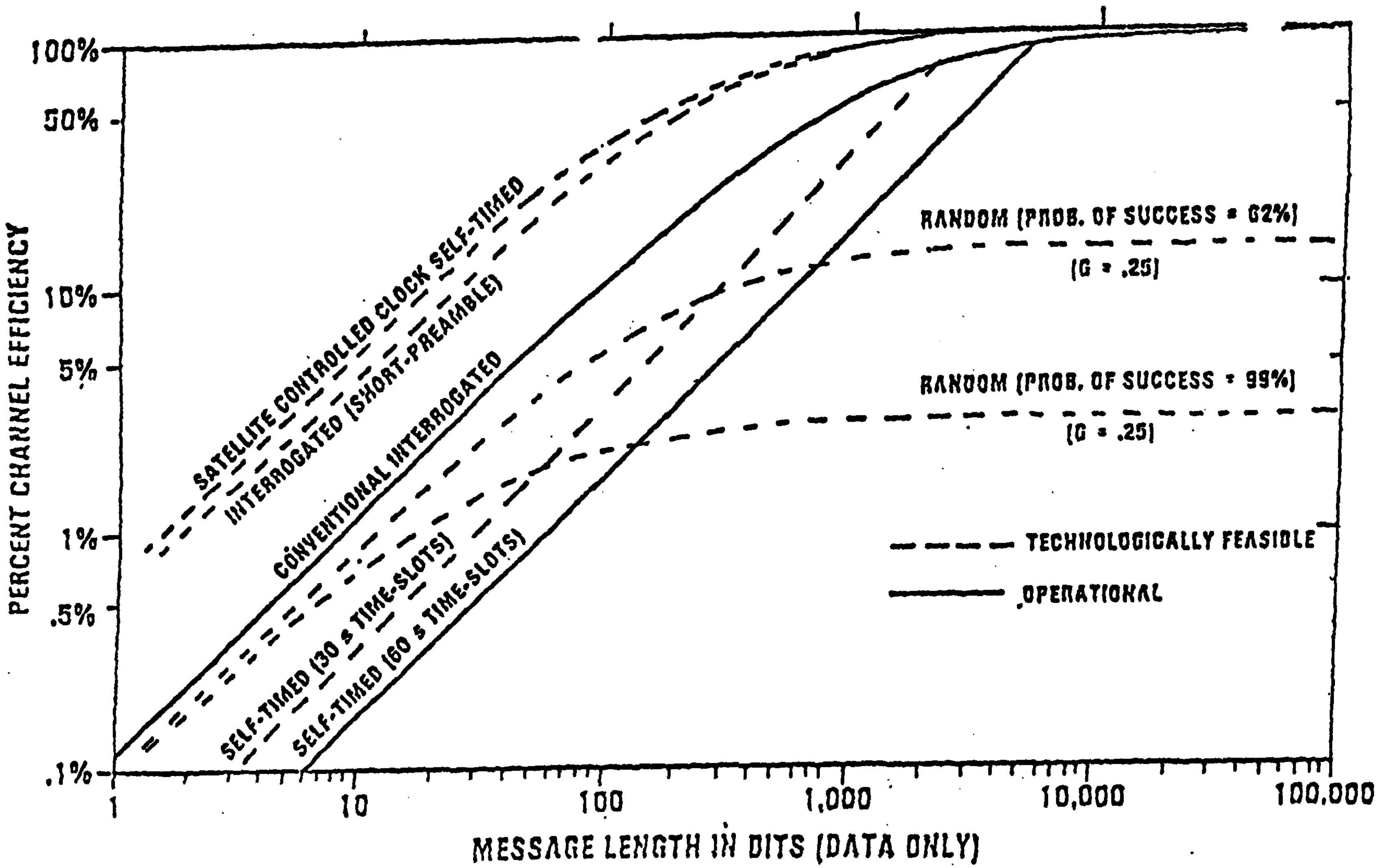

Figure 3.10: Comparison of reporting protocols for the GOES data collection system (6)

significantly be reduced (below the 0.184 maximum) if messages of the various DCP's are of different lengths. In this report message lengths will be assumed the same for all users. Metzner (16) shows that throughput can be increased (by about 50 percent) by grouping transmitters into high and low power sets. The concept is that although collisions may occur, high power transmissions may override low power ones and still be received correctly. We will continue using the conservative view that all DCP's have the same power, and collisions lead to complete loss of data.

Sant (13) studies random reporting both by relaxing the assumption of exponential inter-arrival times and by letting each DCP have an arbitrary distribution of message transmission. He shows that when the traffic load, G_i, of each station i is small, relative to the total traffic G (the common case), the throughput becomes the same as that of the unslotted ALOHA system (Equation 3.16). Furthermore the throughput will always be bounded by the unslotted and slotted ALOHA results (between Equations 3.16 and 3.23). In summary the Poisson arrival model is very robust in a statistical sense.

For the Corps and most environmental data users the main concern is the low reliability of message reception achieved with the random reporting scheme. The NESS Users Guide for Random Reporting (6) proposes three methods to increase probability of successful transmissions without changing protocols.

1. <u>one short transmission per message</u>: so as to achieve high probability of success for a single transmission (i.e., $G = 0.025$ leads to $P_s = 0.95$).

2. <u>K short transmissions per message</u>: random spacing of the identical messages to raise probability that at least one of the K trials was successful. This effectively leads to increasing transmission rates by K while keeping message duration constant.

3. <u>K messages in one long transmission</u>: append last K-1 messages to current transmission, leading to K opportunities (trials) to successfully receive the data. This effectively increases message duration by K and keeps transmission rates constant.

The first method can be analyzed directly using Equations (3.15) and (3.16). Methods 2 and 3 require the following fairly simple extension.

Interpret transmission as an independent trial. Define

$$P = \text{probability } [\text{one or more successes in K trials}]$$
$$= 1 - \text{probability } [\text{no successes in K trials}]$$

Assuming Bernoulli trials

$$P = 1 - (1 - P_s)^K \quad (3.25)$$

Substituting from Equation (3.15):

$$P = 1 - (1 - e^{-2G})^K \quad (3.26)$$

This equation can be used to evaluate the effect of message rep. .ion on channel performance. For method 2 the effective total traffic, is $G = N(T_0 + T_1)K\overline{\lambda}$ where $\overline{\lambda}$ is the average transmission rate of a station in the network; T_0 is some overhead time associated with each transmission; and T_1 is the duration of data transmission. For method 3, $G = N\,\overline{\lambda}\,(T_0 + KT_1)$.

Figure 3.11 shows, assuming a target reliability for one or more messages of P = 0.95, λ = 1/hour, and T = 2, 4, and 8 seconds, the maximum numbers of identical platforms that can share a channel under various repetition regimes. Note that Method 3 always provides a greater number of platforms for a given level of reliability than Method 2 or Method 1, the poorest of the three alternatives. Figure 3.12 provides similar results when the target probability of success is 0.99

For the cases shown, up until roughly K = 3 to 5 repetitions, the number of platforms able to share a single channel increases dramatically. Beyond this point, the increase in number of platforms able to share a channel is very small. For large K, this number will actually start to decrease as the channel becomes heavily loaded. This gives guidance as to the optimal number of message repetitions.

If efficiency (numbers of platforms) were the only objective, then Method 3 should always be employed for the given example, which approximates GOES hydrometeorological system user characteristics. Nevertheless, recall that another criterion is the timeliness of message receipt. Under Method 1, or cases where K = 1, there is no delay

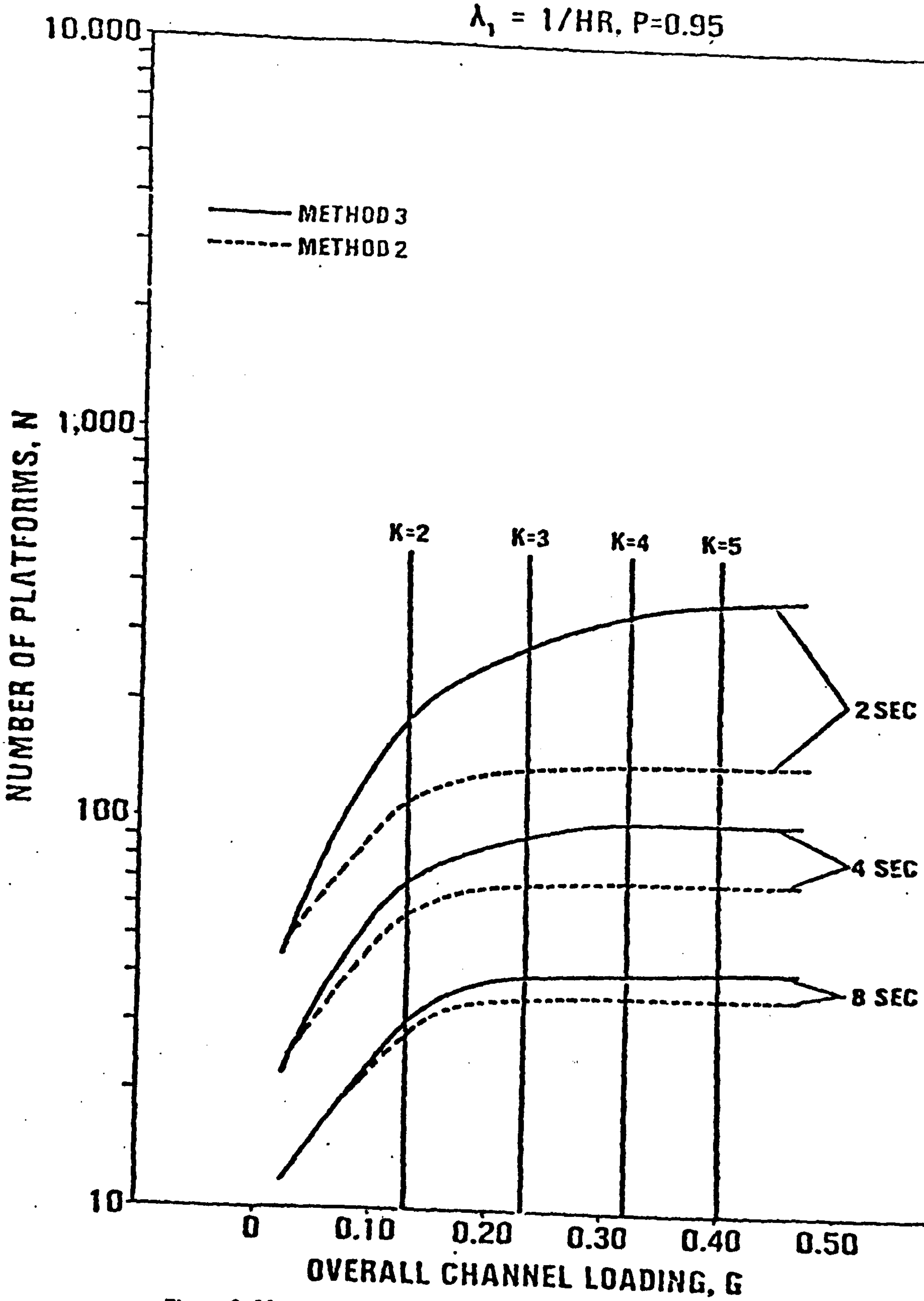

Figure 3.1.1 OVERALL CHANNEL LOADING AS A FUNCTION OF THE NUMBER OF CHANNELS FOR λ = 1 HR, P = 0.95 (6)

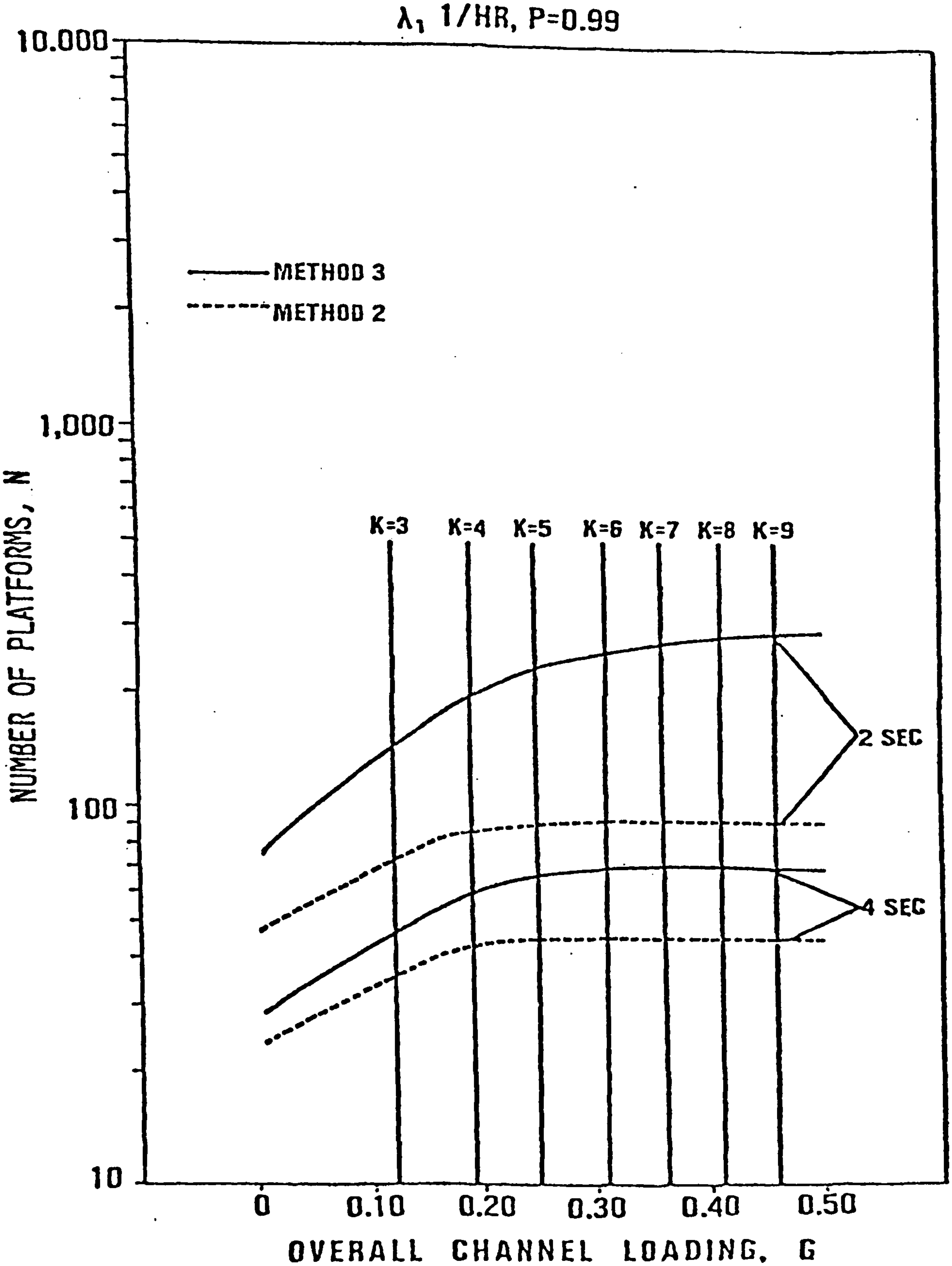

Figure 3.12 OVERALL CHANNEL LOADING AS A FUNCTION OF THE NUMBER OF CHANNELS FOR λ = 1 HR, P = 0.99 (6)

between message receipt and transmission. Under Method 2, a constant one-half hour delay is observed (for the T = 2 seconds case). Under Method 3, the average delay increases as a function of the number of repetitions as $(K - 1) \times 1/2$ hour. Clearly, if timeliness is a concern, the user faces a tradeoff between timeliness and efficiency.

The Users Guide for Random Reporting (6) recommends Method 2 based as offering the best compromise between timeliness and efficiency, and we agree. Furthermore, that document correctly recognizes from the figures that with a channel loading of G = 0.25, three and five repetitions virtually guarantee 95 and 99 percent success probabilities respectively. Higher loadings and repetitions lead to diminishing and insignificant improvements in the number of platforms possible. Using that criterion and the definition of G leads to

$$G = 0.25 = NK\bar{\lambda}T$$

or the maximum number of stations is:

$$N_{max} = (4K\bar{\lambda}T)^{-1} \qquad (3.27)$$

With K equal to 3 and 5 repetitions, with N_{max} or fewer stations, success probabilities should be at least 0.95 and 0.99,respectively.

Equation 3.27 is a good criterion and will play a major role in the analysis of the next Chapter. As it stands, it requires that $\bar{\lambda}$, the average station reporting rate, is a known fixed quantity. This is not the case when DCPs adapt to temporally and spatially varying hydrologic events.

Chapter 4

Network Design Criteria and Analysis Procedures

4.1 Introduction

Chapter 3 discussed the tools and techniques that have been proposed for the study of random reporting networks. Chapter 2 described the nature of Data Collection Platforms and their use in monitoring environmental data. In this chapter we intend to establish guidelines for the design of a national network of DCP's.

It was obvious in Chapter 2 that the number of active data collection platforms is expected to increase dramatically over coming years, with numbers on the thousands foreseen in the near future. For the Corps of Engineers, NESS, and other users, this presents a major planning and logistics problem. Some of the issues that will arise are:

1. Allocation of satellite channels (frequencies) to users.
2. Efficient distribution of data in the satellite-user leg of the communication system.
3. Reliability of hardware and communication links.
4. Fair distribution of resources and satellite access.
5. Control and policing of users' actions that may lead to system failure or overload.
6. Insure equitable and reliable message reception for various users while maximizing utilization of resources.

This work really addresses point number 6 above. It is assumed that:

1. NESS will provide a limited number of frequencies to be used in random reporting, limited with respect to the number of users.
2. The communication downlink between satellite and user is not a problem.
3. Hardware reliability is good.
4. Control and policing activities will develop and conform to the assumptions made in the nation-wide network design algorithm. This last point is particularly important since, as was discussed in Chapter 2, the options on DCP configurations and reporting algorithms are practically infinite. It is expected that C of E will have to maintain some control on this configuration so as to satisfy design assumptions as closely as possible.

Point 6 remains a problem because it cannot be addressed solely with the procedures discussed in Chapter 3. There it is assumed that all DCPs are transmitting at a <u>known</u> rate. In fact, the reporting will adapt according to the magnitude of environmental excitation. It would be possible to make the assumption that all stations respond at the maximum possible rate. Given the fact that rainfall and runoff (the 2 environmental inputs of most interest to C of E) vary widely in space and time over the continental U.S.A., such an assumption would be extremely conservative and an expensive proposition. Notice from Figure 3.11 that assuming a modest transmission rate of 1 per hour, 3 repetitions, 2 seconds messages and the recommended loading (G) of 0.25 to achieve 95% reliability, the maximum number of stations per channel would be about 150, a number not much above the needs of a single C of E district.

This chapter will propose a methodology to explicitly include the variability of environmental parameters in time and space in the decision of how to allocate channels to users. The methodology is of descriptive nature. Given a set of parameters, e.g., possible reporting rates, number of stations per user, climatic characteristics, message duration, etc., the procedure will evaluate the level of performance of the system. An alternative would have been a prescriptive model that would configure the network so as to optimize a given set of objectives. This approach was not taken due to the difficulties in quantifying the possibly many and conflicting objectives of users and managers. Many of the ultimate design decisions should remain functions of unquantifiable policy goals.

The methodology is <u>not</u> a simulation model. This approach would have been unjustified given present uncertainty on number and possible locations of stations and given the nature of data available. Computationally it would have become an unwieldy exercise that could obscure results rather than illuminate them.

4.2 Streamflow versus Rainfall

The Army Corps of Engineers and other users are in fact mostly interested in river discharge. Data Collection Platforms can be driven by streamflow or rainfall. Streamflow is, nevertheless, a very local behavior. The river basin and sub-basins are filters that transform high frequency rainfall into low frequency streamflow. Although it may be raining over a large area, the affected river basins transform this input differently. They introduce time delays and storage effects so that even a highly correlated spatial input will result in uncorrelated hydrographs, time distribution of discharge at various points will not coincide at all within or among basins. So the use of rainfall as the focus of the methodology tends to overestimate the response rate and correlation among platforms. Rainfall will probably require high sampling rates concurrently over large areas to an extent not probable with streamflow.

Due to the local nature of streamflow, it makes no sense to generalize behavior. It only makes sense to talk about response where the stations are located. At this point it is not known where stations are located and furthermore it would be an unmanageable task to look at all local behavior over thousands of locations even if the sites and data were available.

Streamflow behavior is also so dependent on antecedent conditions that generalizations of behavior from rainfall analysis seem unwise.

In summary for this project rainfall was chosen as the DCPs' triggering phenomena. It is a conservative assumption in terms of DCP performance; data is easily generalized due to its homogeneous characteristics over areas and its statistical stationarity over the time scales of interest; and as will be seen, reasonably good data sources are available.

Acknowledgeably, this decision will introduce several problems of operational nature. One is how can C of E district officers "translate" reporting rates associated with discharges to rates associated with rainfall. Second is the decision over what time step rainfall is going to be studied. These issues will be discussed in Chapter 6 and 5 respectively.

4.3 Network Design Algorithm

Several assumptions are made in the suggested approach:

1. A "user" is defined as a Corps of Engineers District or any other non-overlapping geographical unit.
2. All users employ the same message length and will strive for message reliability using repetition method 2 as described in the "Users Guide for Random Reporting" (6) and Chapter 3. The number of repetitions is taken to be at least 3, the same for all users.
3. All stations within a user have the same adaptive reporting rate algorithm. This implies the same "threshold and slope" parameters. Different users can have different parameters.
4. Trading of unit loads between users will not be allowed.

5. Each user will attempt to use up to their available unit loads. A unit load is presently defined by NESS as 120 sec. per day per station or 5 sec. per hour per station. This is considered a parameter in the technique in that it can be varied.

6. Each user will design its network for a "worst" local condition. The meaning of "worst" will be expanded later; it refers to possible combinations of reporting rates.

The approach taken identifies two constraints in DCP deployment and use.

1. NESS limits each user by the unit load concept. Therefore, each user cannot exceed its quota.

2. Message reliability has to be reasonably high for all users. The reliability of each user is very much dependent on other users, even though each user operating alone would not run into a reliability problem.

With the above in mind the network design is taken in two steps: one local and one national. At the local level each user configures its network by selecting the criteria of maximizing its information, i.e., using as much of the unit loads available to him. At this level reliability will rarely be a problem, but it will be checked. At the national level, all users, after their local design, must satisfy a given level of message reliability. If the national network fails to satisfy this reliability level, the design reverts to the local level where adjustments in number of stations and/or reporting rates must be made. How to allocate these adjustments will be further discussed.

4.3.1. Procedural Details

The underlying difficulty in the above outlined design philosophy is that the DCP's are activated at various reporting rates by a random climate. Therefore, the local and national constraints can be nationally satisfied only at a given level of probability.

The unit load limitation was discussed in Chapter 3 and is presently established by NESS. Reliability will be tested using the results given in the "Users Guide for Random Reporting" and Chapter 3. Based on good analysis and rationale, it was there concluded that 95% reliability could be achieved by using repetition Method 2 with 3 repetitions and a channel loading of 0.25. Channel loading is defined by

$$G = N\,K\,\bar{\lambda}\,T \qquad (4.1)$$

where $\bar{\lambda}$ is the average station reporting rate of the system in messages per second, T is the message duration in seconds, K is the number of repetitions and N is the number of stations. A reliability of 99% could be achieved by repeating 5 times and having the same channel loading. With the above, it followed that for a known average station reporting rate, $\bar{\lambda}$ (transmissions per second), the maximum number of stations possible (and still maintain reliability) is,

$$N_{max} = (4\,K\,\bar{\lambda}\,T)^{-1} \qquad (4.2)$$

Notice, though, that due to the random climate, $\overline{\lambda}$ is a random variable. Therefore, unless λ is taken at the extremely conservative maximum possible value, there is a finite probability of having $(4\ K\ \overline{\lambda}\ T)^{-1} > N_{max}$ which will lead to lower reliability. The probability of this occurrence is a design criterion.

4.3.1.1 <u>Local Design</u>

A user will proceed as follows:

1. A number of desired stations, N_j, is fixed, based on need, tradition, etc. Subscript j indicates the user.
2. User j unit loads are given by

$$\sum_{i=1}^{N_j} K^{\bullet}\lambda_{ij} \cdot 3600(sec/hr)*T(sec)/5(sec/hr/u.l.)$$

where λ_{ij} is the number of messages per second at station i of user j. There are 5 seconds per hour per unit load. The above is reformulated in light of the randomness of λ_{ij} as:

$$K^{\bullet}\overline{\lambda}_j \cdot 3600 \cdot T/5 \ \leq 1 \text{ with probability } P_0 \qquad (4.3)$$

where $\overline{\lambda}_j$ is a random variable representing the average transmission rate of user j stations and is given by:

$$\overline{\lambda}_j = \frac{1}{N_j} \sum_{i=1}^{N_j} \lambda_{ij} \qquad (4.4)$$

$\overline{\lambda}_j$ is a random variable because each station response rate, λ_{ij}, is unknown and dependent on the precipitation input. For reasons that will be apparent in Chapter 5, when the available climate information is discussed, the adaptive reporting algorithm will be modified so that λ_{ij} can take one of n values, depending on the rainfall accumulation of a rainfall event. For the sake of clarity, take n=8. So,

$$\lambda_{ij} = \{b_{1j}, b_{2j}, b_{3j}, b_{4j}, b_{5j}, b_{6j}, b_{7j}, b_{8j}\} \qquad (4.5)$$

The eight rates could depend (for example) on the following 8 rainfall conditions in any one station, respectively: 1) no rainfall (or $\leq$ 0.01 inches), 2) rainfall between 0.01 and 0.5 inches, 3) rainfall between 0.5 and 1.0 inches, 4) rainfall between 1.0 and 1.25 inches, 5) rainfall between 1.25 and 1.50 inches, 6) rainfall between 1.5 and 2.0 inches, 7) rainfall between 2.0 and 3.0 inches, and 8) rainfall greater than 3.0 inches.

Equation 4.4 is a sum of random variables with distribution that will tend to normality reasonably fast as N_j increases, given that the distribution of total rainfall in each location is generally accepted to be nearly gamma distributed (31). Assuming normality the parameters required to fully define the distribution of $\bar{\lambda}_j$ are then its mean and variance.

The mean of $\bar{\lambda}_j$ is given by:

$$\hat{\lambda}_j = \frac{1}{N_j} \sum_{i=1}^{N_j} \hat{\lambda}_{ij} \tag{4.6}$$

where $\hat{\lambda}_{ij}$ is the mean reporting rate at each station of user j. This mean is given by

$$\hat{\lambda}_{ij} = b_{1j} . P \text{ [no rainfall in i]}$$

$$+ \sum_{\ell=2}^{8} b_{\ell,j} \;.\; P \text{ [rainfall in interval } \ell \text{ and it rains in i]} \tag{4.7}$$

The notation P[.] implies the probability of the event described within brackets.

The variance of $\bar{\lambda}_j$ is,

$$Var[\bar{\lambda}_j] = \left(\frac{1}{N_j}\right)^2 \left[\sum_{i=1}^{N_j} Var(\lambda_{ij}) + \sum_{i_1 \neq i_2} \sum_{i_2} cov(i_1, i_2) \right] \tag{4.8}$$

In the above the variance of λ_{ij} is given by

$$\begin{aligned} Var[\lambda_{ij}] &= (b_{ij} - \hat{\lambda}_{1j})^2 \; P \text{ [no rainfall in i]} \\ &+ \sum_{\ell=2}^{8} (b_{\ell,j} - \hat{\lambda}_{ij})^2 \; P \text{ [rainfall in interval } \ell \text{ and it rains in i]} \end{aligned} \tag{4.9}$$

The covariance between point i_1 and i_2 of user j, $cov(i_1, i_2)$ is given by:

$$cov(i_1, i_2) = E\,[(\lambda_{i_1 j} - \hat{\lambda}_{i_1 j})(\lambda_{i_2 j} - \hat{\lambda}_{i_2 j})]$$

$$\begin{aligned} &= (b_{1j} - \hat{\lambda}_{i_1 j})(b_{1j} - \hat{\lambda}_{i_2 j}) \; . \; P \text{ [no rain in } i_1 \text{ \underline{and} no rain in } i_2] \\ &+ \sum_{\ell=2}^{8} (b_{1j} - \hat{\lambda}_{i_\ell j})(b_{\ell j} - \hat{\lambda}_{i_2 j}) \; . \; P \text{ [rainfall in interval } \ell \text{ and it rains in } i_2 \text{ \underline{and} \underline{not} in } i_1] \\ &+ \sum_{\ell=2}^{8} (b_{\ell j} - \hat{\lambda}_{i_1 j})(b_{1j} - \hat{\lambda}_{i_2 j}) \; . \; P \text{ [rainfall in interval } \ell \text{ and it rains in } i_1 \text{ \underline{and} \underline{not} in } i_2] \\ &+ \sum_{\ell_2 = 2}^{8} \sum_{\ell_1 = 2}^{8} (b_{\ell_1 j} - \hat{\lambda}_{i_1 j})(b_{\ell_2 j} - \hat{\lambda}_{i_2 j}) \; . \; P \text{ [rainfall in interval } \ell_1 \text{ and it rains in } i_1 \text{ \underline{and} rainfall in internal } \ell_2 \text{ and it rains in } i_2] \end{aligned} \tag{4.10}$$

where E means statistical expectation.

Reasonably assuming that the rainfall <u>amounts</u> are independent and only the occurrence (or not) of rainfall anywhere in space is dependent, some of the probabilities in (4.10) simplify:

P[rainfall in interval ℓ and it rains in i_1 and not in i_2]

= P[rain in interval ℓ|rainfall in i_1].P [rainfall in i_1 and not in i_2]

P[rainfall in interval ℓ_1 and it rains in i_1 <u>and</u> rainfall in interval ℓ_2 and it rains in i_2]

= P[rainfall in interval ℓ_1|rains in i_1].P[rainfall in interval ℓ_2|rain in i_2] . P[rainfall in i_1 and in i_2].

The notation P[A|B] signifies probability of event A given that event B occurs.

3. With the mean and variance of $\overline{\lambda}_j$ now defined, the user can draw its distribution as in Figure 4.1.

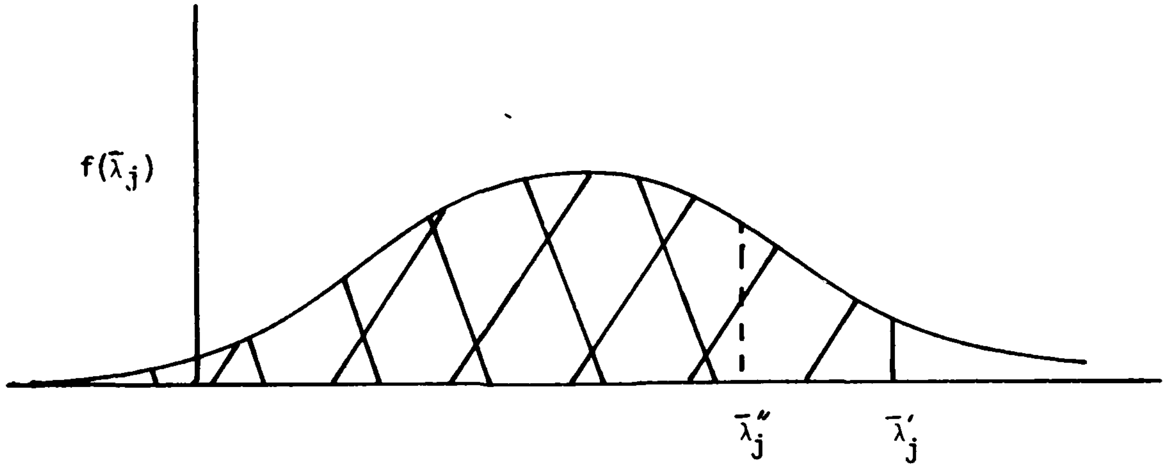

Figure 4.1: Probabilistic Distribution of $\bar{\lambda}_j$

The user solves the unit load equality implied by Eq. 4.3,

$$\bar{\lambda}_j' = \frac{5}{3600\ T\ K} \tag{4.11}$$

and plots it in Figure 4.1. The area under the curve up to $\bar{\lambda}_j'$ is the probability that a reporting rate less than or equal to $\bar{\lambda}_j'$ is observed. If this area is greater or equal to P_o then the user desired N_j and reporting rates (Equation 4.5) are acceptable. If not, N_j must be reduced or the possible reporting rates reduced until the criterion is satisfied.

4. Once the unit load inequality of Eq. 4.3 is satisfied at a given probability level, the user may use Equation 4.2 with his chosen N_j to obtain

$$\overline{\lambda}''_j = \frac{1}{4\ N_j\ T\ K} \qquad (4.12)$$

If $\overline{\lambda}''_j \geq \overline{\lambda}'_j$, then the user is satisfying unit loads limitation with message success probabilities of 95% or more with probability P_o. If $\overline{\lambda}''_j < \overline{\lambda}'_j$ then the cross hatched area in Figure 4.1 gives the probability (less than P_o) that successful messages be received 95% of the time. If this probability is unacceptable, the user's only choice is to further reduce N_j or the report.. rates.

4.3.1.2 National Design

At the national level, the premise is that unit load restrictions are satisfied and the issue is to achieve a given level of message success at a given probability level. Using Equation 4.2 on a national scale:

$$\overline{\lambda}_* = 1.0/4\ N\ T\ K \qquad (4.13)$$

where $N = \sum_{j \epsilon J} N_j$ and $j \epsilon J$ means that j is an element in the set J of DCP's using a common channel.

The rate $\overline{\lambda}_*$ is the average station rate that would be required to achieve 95% message success probability in a system with deterministic response rates. Given the variable national climate, in fact the average national reporting rate per station,

$$\bar{\lambda} = \frac{1}{m} \sum_{j \varepsilon J} \bar{\lambda}_j = \frac{1}{m} \sum_{j \varepsilon J} \frac{1}{N_j} \sum_{i=1}^{N_j} \lambda_{ij} \tag{4.14}$$

is a random variable, again with distribution approaching normality. m is the number of users in set J.

The mean of $\bar{\lambda}$ is,

$$\hat{\lambda} = \frac{1}{m} \sum_{j \varepsilon J} \hat{\lambda}_j \tag{4.15}$$

where $\hat{\lambda}_j$ was given by Equation 4.6.

The variance of $\bar{\lambda}$, var($\bar{\lambda}$), is

$$\mathrm{Var}\,[\bar{\lambda}] = \frac{1}{m^2} \sum_{j \varepsilon J} \mathrm{var}\,[\bar{\lambda}_j]$$

$$+ \frac{1}{m^2} \sum_{j_1 \varepsilon J} \sum_{\substack{j_2 \varepsilon J \\ j_1 \neq j_2}} \frac{1}{N_{j_1} N_{j_2}} \sum_{i_1 \varepsilon N_{j_1}} \sum_{i_2 \varepsilon N_{j_2}} \mathrm{cov}(i_1, i_2) \tag{4.16}$$

where the terms have been previously defined. Having $\hat{\lambda}$ and var[$\bar{\lambda}$], the distribution of $\bar{\lambda}$ can be drawn as in Figure 4.2.

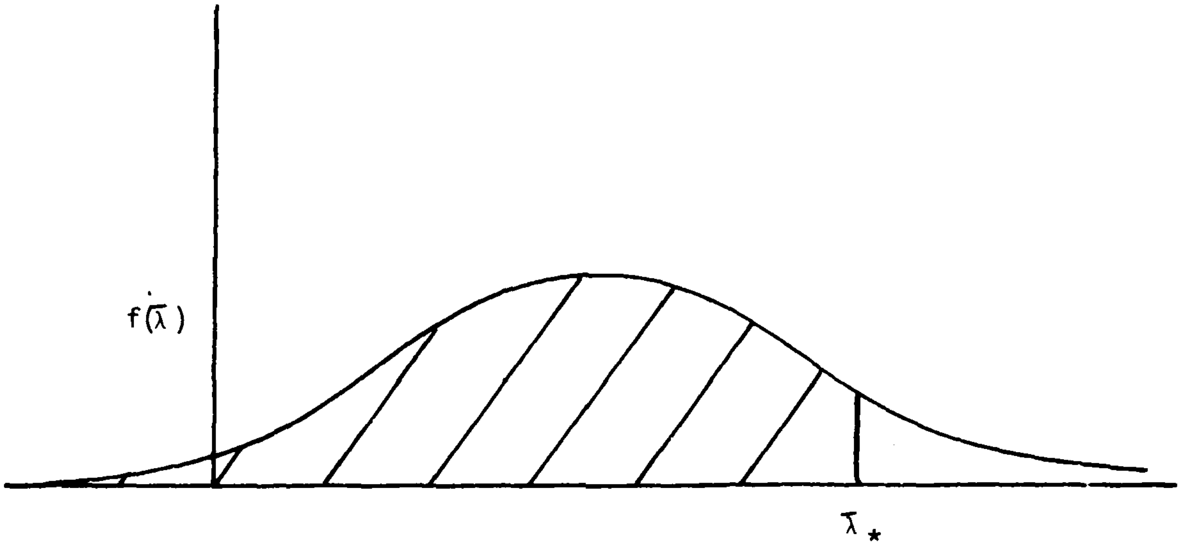

Figure 4.2: Distribution of National Reporting Rate $\bar{\lambda}$

If $\bar{\lambda}_*$ as given by 4.13 plots in Figure 4.2 such that the area below it is greater or equal than to a pre-specified level P_1, then the National system satisfies all criteria: all users satisfy unit load restrictions with probability P_0 and national system achieves 95% (or whatever chosen level) success rate with probability P_1. If the area under $\bar{\lambda}_*$ is less than P_1, then the alternatives are:

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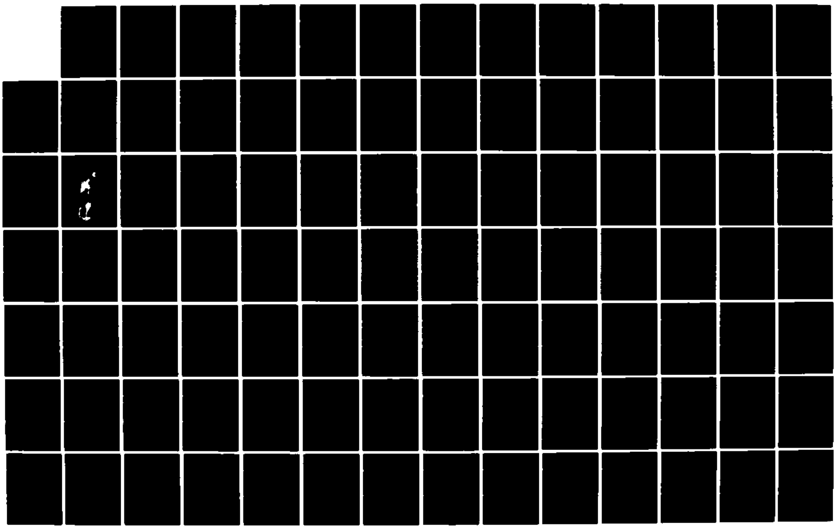
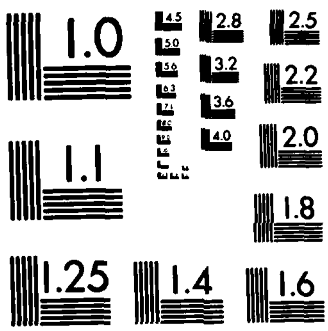




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1) try a different combination of users in the channel, a a different set J.

2) require users to reduce the reporting rate.

3) and/or reduce the total number of stations in the national network by requiring users to reduce their number of stations.

There is a political and equity issue unsolved in going back to users to force redesign, if it comes to that. Within the proposed scheme, equity would be defined by making the distribution of $\bar{\lambda}_j$ (Figure 4.1) look the same for all users j. Clearly, though, this objective is flawed since it could possibly force some users to <u>increase</u> rates and numbers of stations. Therefore, downward adjustments should start with 1) users with large $\hat{\lambda}_j$ and large variance, var$[\bar{\lambda}_j]$; 2) users with small areas below λ_j'' in Figure 4.1; 3) users approaching the P_0 criterion in satisfaction of unit load requirements.

Chapter 5

Climatic Data Analysis

5.1 Required Climatic Analysis

To perform the analysis presented in Chapter 4, we require the definition of:

1) P [no rainfall in i]
2) P [rainfall in depth interval ℓ <u>and</u> rainfall in i]
3) P [no rain in i_1 <u>and</u> no rain in i_2]
4) P [rainfall in i_1 <u>and</u> <u>not</u> in i_2]
5) P [rainfall in i_2 <u>and</u> <u>not</u> in i_1]
6) P [rainfall in i_1 <u>and</u> in i_2]

Inherent in the formulation and in the above required probabilities are several assumptions:

1) we have information on storm accumulation;
2) the above probabilities exist for <u>known</u> locations of DCP's.

Both of the above are not true, so approximations are required. For the sake of feasibility, the <u>daily</u> rainfall accumulations are taken as surrogates of storm depth. Clearly this is in error if multiple storms occur in a day and/or if storms last longer than a day. We feel that most important occurrences will be well represented within this

24-hour period. The choice will create operational problems in making streamflow-rainfall comparisons, necessary to rationally obtain reasonable and valid reporting rates, b_{ij}, needed for analysis. This will be addressed in Chapter 6. On the other hand, a 24-hour accumulation of rainfall will lead to higher correlations in space, a conservative assumption that will tend to limit allowable numbers of DCP's in a channel.

The assumption that potential locations of DCP's are known and that the necessary data or probabilities exist is untenable. At best, the necessary data will be available (as will soon be presented) over a reasonably dense grid covering the conterminous United States. The agreement of grid points with a future or existing DCP location would be coincidental. Given the above situation, it will be assumed that available data (at points) are representative of a homogeneous climate over its "area of influence." Its area of influence will be defined by its corresponding Thiessen polygon. It will then be assumed that DCP's within a polygon have the probabilistic and climatic characteristics of the corresponding data point. Since the locations of potential DCP's within users, C of E Districts, are not known, it will be further assumed that they will be uniformly distributed within each District. For example (see Figure 5.1), define N_j as the number of stations in District j, in the Figure there are 2 districts separated by a sinuous boundary; define a_{ij} as the sub-area of the Thiessen polygon i (i.e., data point i) within district j; and A_j the area of district j. Then, the number of stations in district j, responding to the climate of data point i is,

$$N_{ij} = \frac{a_{ij}}{A_j} N_j \tag{5.1}$$

Say that in Figure 5.1, if the area of district 2, A_2, were 100, with $a_{12} = 70$, $a_{32} = 25$, and $a_{42} = 5$, and if 100 DCP were to be allocated for District 2, then there would be

$$N_{12} = \frac{70}{100} 100 = 70$$

DCP's responding according to the climate of point 1, and

$$N_{32} = \frac{25}{100} 100 = 25$$

responding according to point 3 and similarly 5 (or N_{42}) responding according to point 4.

5.2 Climatic Data Sources

A search of literature and data sources yielded several good leads in the statistics of rainfall over the U.S.A. A brief summary of these sources follows:

1. Klein [32] gives a complete study of tracks (primary and secondary) as well as the frequency of genesis of low pressure

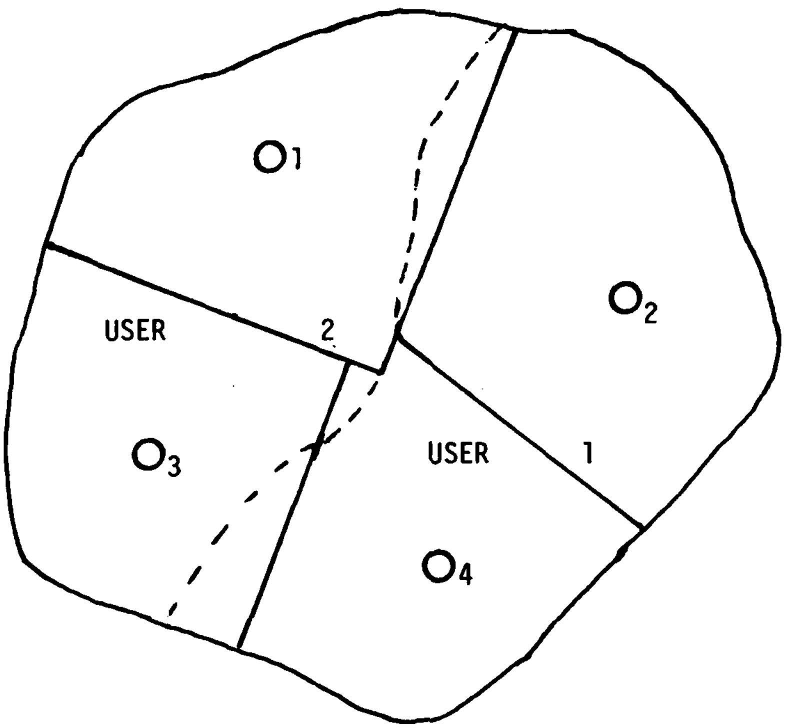


Figure 5.1: Schematic diagram showing two users and four precipitation stations with corresponding Thiessen polygons

centers (cyclones) over the Northern Hemisphere. This information is peripheral, but it could provide qualitative information as to where to expect correlation between the occurrence of storm events.

2. Jorgensen and Jorgensen, et al, [30, 31] use a data set with 108 stations over the conterminous U.S.A. and 15 years of record to:

   a) give the probability of rainfall in any of the 108 stations, on a monthly and seasonal basis for any of 7 different time periods in a day (0-6, 6-12, 12-18, 18-24, 0-12, 12-24, 0-24).

   b) give the probability of rainfall depths in 7 intervals (0.01-0.1, 0.1-0.25, 0.25-0.50, 0.50-1.00, 1.00-1.5, 1.5-2.0, 2.0 or greater) conditional on the occurrence of rainfall in any of the 108 stations for the 7 different time periods described above for four seasons.

   c) give the number of "wet" and "dry" periods per station, per season.

   d) hypothesize that climatic behavior over the U.S.A. can be divided in

      -- east and west of the Rockies

      -- and according to average rainfall accumulation per wet period.

   e) hypothesize that rainfall depths are gamma distributed.

The original data set of Jorgensen is apparently lost and efforts to obtain it failed.

3. A very complete data set was located at the University of Illinois. After extensive discussions the following has been concluded:

   a) The full data set includes 51 tapes. Processing of desired stations, including some accounting for data errors is infeasible due to budget limitations.

   b) A data subset of about 200 stations exists. Unfortunately, this is <u>storm</u> data. The actual time of storm occurrence is not preserved in the subset. Our analysis is impossible without this information.

4. Some recent literature (34) argues that the distribution of storm areas may be obtained from point (station) information. This applies to <u>homogeneous</u> climatic regions. In order to use this concept, we must make <u>subjective</u> assessment of these regions. This is possible, but considered a secondary approach to obtain the information we needed.

5. The N.W.S. Techniques Development Laboratory uses a data set containing about 10 years of data, in an hourly basis, for about 250 stations throughout the U.S.A. The Techniques Development Laboratory cooperated in selling us this information. The nature of these data will be better defined in the next subsection. It is important to state that this data set is the one used to calibrate weather forecasting models used by the N.W.S.

It is important to note that Jorgensen, et al, (31) provide us with the first 2 probabilities needed in this analysis. As Section 5.3 will discuss, it is possible to approximate all the necessary probabilistic information from their analysis. A more complete approach uses TDL's raw data. This alternative, although considerably more computationally burdensome, was selected. It is discussed in Section 5.4.

5.2.1 The Techniques Development Laboratory (TDL) Data Set

The National Weather Service's Techniques Development Laboratory compiles data for 255 stations: 236 over the conterminous U.S.A., 14 in Alaska, 4 in Hawaii, and 1 in Puerto Rico. The data includes several parameters, viz., precipitation, temperature, dew point temperature, wind, etc., and is stored in 3 hour intervals. These data are utilized to develop meteorological predictors which form part of the Multiple Output Statistics (MOS) system (33).

The Techniques Development Laboratory agreed to sell a portion of this data set. Analyzed were daily rainfall accumulations of the 236 stations over the conterminous U.S.A. The period of record available consists of 9 years from October 1, 1972 through September 30, 1981. An alphabetical listing of all stations is given in Table 5.1.

Table 5.1: Names of Stations in Techniques Development Laboratory Data Set (33)

	STATION	ID NUMBER
1	3103FLAGSTAFF, ARIZ	1
2	3812ASHEVILLE, NC	2
3	3813MACON, GA	3
4	3820AUGUSTA, GA	4
5	3822SAVANNAH, GA	5
6	3856HUNTSVILLE, ALA	6
7	3860HUNTINGTON, W VA	7
8	3870GREENVILLE, SC	8
9	3872BECKLEY, W VA	9
10	3927FORT WORTH, TEX	10
11	3928WICHITA, KANS	11
12	3937LAKE CHARLES, LA	12
13	3940JACKSON, MISS	13
14	3945COLUMBIA, MO	14
15	3947KANSAS CITY, MO	15
16	4725BINGHAMTON, NY	16
17	4751BRADFORD, PA	17
18	11641SAN JUAN, P.R.	18
19	12834DAYTONA BEACH, FLA	19
20	12835FORT MYERS, FLA	20
21	12836KEY WEST, FLA	21
22	12839MIAMI, FLA	22
23	12841ORLANDO, FLA	23
24	12842TAMPA, FLA	24
25	12844WEST PALM BEACH, FLA	25
26	12884BOOTHVILLE, LA	26
27	12912VICTORIA, TEX	27
28	12916NEW ORLEANS, LA	28
29	12919BROWNSVILLE, TEX	29
30	12921SAN ANTONIO, TEX	30
31	12924CORPUS CHRISTI, TEX	31
32	12960HOUSTON, TEX	32
33	13722RALEIGH-DURHAM, NC	33
34	13723GREENSBORO, NC	34
35	13729ELKINS, W VA	35
36	13733LYNCHBURG, VA	36
37	13737NORFOLK, VA	37
38	13739PHILADELPHIA, PA	38
39	13740RICHMOND, VA	39
40	13741ROANOKE, VA	40
41	13743WASHINGTON, DC	41
42	13748WILMINGTON, NC	42
43	13781WILMINGTON, DEL	43
44	13865MERIDIAN, MISS	44
45	13866CHARLESTON, W VA	45

Table 5.1: Cont.

	STATION	ID NUMBER
46	13873ATHENS, GA	46
47	13874ATLANTA, GA	47
48	13876BIRMINGHAM, ALA	48
49	13877BRISTOL, TENN	49
50	13880CHARLESTON, SC	50
51	13881CHARLOTTE, NC	51
52	13882CHATTANOOGA, TENN	52
53	13883COLUMBIA, SC	53
54	13889JACKSONVILLE, FLA	54
55	13891KNOXVILLE, TENN	55
56	13893MEMPHIS, TENN	56
57	13894MOBILE, ALA	57
58	13895MONTGOMERY, ALA	58
59	13897NASHVILLE, TENN	59
60	13899PENSACOLA, FLA	60
61	13935ALEXANDRIA, LA	61
62	13957SHREVEPORT, LA	62
63	13958AUSTIN, TEX	63
64	13959WACO, TEX	64
65	13960DALLAS, TEX	65
66	13962ABILENE, TEX	66
67	13963LITTLE ROCK, ARK	67
68	13964FORT SMITH, ARK	68
69	13966WICHITA FALLS, TEX	69
70	13967OKLAHOMA CITY, OKLA	70
71	13968TULSA, OKLA	71
72	13970BATON ROUGE, LA	72
73	13984CONCORDIA, KANS	73
74	13985DODGE CITY, KANS	74
75	13993ST JOSEPH, MO	75
76	13994ST LOUIS, MO	76
77	13995SPRINGFIELD, MO	77
78	13996TOPEKA, KANS	78
79	14606BANGOR, ME	79
80	14607CARIBOU, ME	80
81	14732NEW YORK, NY	81
82	14733BUFFALO, NY	82
83	14734NEWARK, NJ	83
84	14735ALBANY, NY	84
85	14737ALLENTOWN, PA	85
86	14739BOSTON, MASS	86
87	14740HARTFORD, CONN	87
88	14742BURLINGTON, VT	88
89	14745CONCORD, NH	89
90	14751HARRISBURG, PA	90

Table 5.1: Cont.

STATION	ID NUMBER
91 14764PORTLAND, ME	91
92 14765PROVIDENCE, RI	92
93 14768ROCHESTER, NY	93
94 14771SYRACUSE, NY	94
95 14777WB SCRANTON, PA	95
96 14778WILLIAMSPORT, PA	96
97 14819CHICAGO MIDWAY, ILL	97
98 14820CLEVELAND, OHIO	98
99 14821COLUMBUS, OHIO	99
100 14826FLINT, MICH	100
101 14827FORT WAYNE, IND	101
102 14836LANSING, MICH	102
103 14837MADISON, WIS	103
104 14839MILWAUKEE, WIS	104
105 14840MUSKEGON, MICH	105
106 14842PEORIA, ILL	106
107 14847SAULT ST MARIE, MICH	107
108 14848SOUTH BEND, IND	108
109 14850TRAVERSE CITY, MICH	109
110 14852YOUNGSTOWN, OHIO	110
111 14860ERIE, PA	111
112 14895AKRON-CANTON, OHIO	112
113 14898GREEN BAY, WIS	113
114 14913DULUTH, MINN	114
115 14914FARGO, N DAK	115
116 14918INTL FALLS, MINN	116
117 14920LACROSSE, WIS	117
118 14922MINNEAPOLIS, MINN	118
119 14923MOLINE, ILL	119
120 14925ROCHESTER, MINN	120
121 14929ABERDEEN, S DAK	121
122 14931BURLINGTON, IOWA	122
123 14933DES MOINES, IOWA	123
124 14935GRAND ISLAND, NEBR	124
125 14936HURON, S DAK	125
126 14940MASON CITY, IOWA	126
127 14942OMAHA, NEBR	127
128 14943SIOUX CITY, IOWA	128
129 14944SIOUX FALLS, S DAK	129
130 14991EAU CLAIRE, WIS	130
131 21504HILO, HI	131
132 22010DEL RIO, TEX	132
133 22516KAHULUI, HI	133
134 22521HONOLULU,HI	134
135 22536LIHUE, HI	135

Table 5.1: Cont.

STATION	ID NUMBER
136 23023MIDLAND, TEX	136
137 23034SAN ANGELO, TEX	137
138 23042LUBBOCK, TEX	138
139 23044EL PASO, TEX	139
140 23047AMARILLO, TEX	140
141 23048TUCUMCARI, N MEX	141
142 23050ALBUQUERQUE, N MEX	142
143 23062DENVER, COLO	143
144 23065GOODLAND, KANS	144
145 23066GRAND JUNCTION, COLO	145
146 23090FARMINGTON, N MEX	146
147 23129LONG BEACH, CALIF	147
148 23153TONOPAH, NEV	148
149 23154ELY, NEV	149
150 23155BAKERSFIELD, CALIF	150
151 23159BRYCE CANYON, UTAH	151
152 23160TUCSON, ARIZ	152
153 23161DAGGETT, CALIF	153
154 23169LAS VEGAS, NEV	154
155 23174LOS ANGELES, CALIF	155
156 23183PHOENIX, ARIZ	156
157 23185RENO, NEV	157
158 23188SAN DIEGO, CALIF	158
159 23194WINSLOW, ARIZ	159
160 23195YUMA, ARIZ	160
161 23230OAKLAND, CALIF	161
162 23232SACRAMENTO, CALIF	162
163 23234SAN FRANCISCO, CALIF	163
164 23237STOCKTON, CALIF	164
165 23273SANTA MARIA, CALIF	165
166 24011BISMARCK, N DAK	166
167 24013MINOT, N DAK	167
168 24018CHEYENNE, WYO	168
169 24021LANDER, WYO	169
170 24023NORTH PLATTE, NEBR	170
171 24025PIERRE, S DAK	171
172 24027ROCK SPRINGS, WYO	172
173 24028SCOTTSBLUFF, NEBR	173
174 24029SHERIDAN, WYO	174
175 24033BILLINGS, MONT	175
176 24089CASPER, WYO	176
177 24090RAPID CITY, S DAK	177
178 24121ELKO, NEV	178

Table 5.1: Cont.

	STATION	ID NUMBER
179	24127SALT LAKE CITY, UTAH	179
180	24128WINNEMUCCA, NEV	180
181	24131BOISE, IDAHO	181
182	24134BURNS, OREG	182
183	24143GREAT FALLS, MONT	183
184	24144HELENA, MONT	184
185	24146KALISPELL, MONT	185
186	24153MISSOULA, MONT	186
187	24155PENDLETON, OREG	187
188	24156POCATELLO, IDAHO	188
189	24157SPOKANE, WASH	189
190	24172LOVELOCK, NEV	190
191	24193WENDOVER, UTAH	191
192	24216RED BLUFF, CALIF	192
193	24221EUGENE, OREG	193
194	24225MEDFORD, OREG	194
195	24227OLYMPIA, WASH	195
196	24229PORTLAND, OREG	196
197	24230REDMOND, OREG	197
198	24232SALEM, OREG	198
199	24233SEATTLE-TACOMA, WASH	199
200	24243YAKIMA, WASH	200
201	24283ARCATA, CALIF	201
202	24284NORTH BEND, OREG	202
203	25308ANNETTE, AK	203
204	25309JUNEAU, AK	204
205	25339YAKUTAT, AK	205
206	25503KING SALMON, AK	206
207	25624COLD BAY, AK	207
208	25713ST. PAUL ISLAND, AK	208
209	26411FAIRBANKS, AK	209
210	26451ANCHORAGE, AK	210
211	26510MCGRATH, AK	211
212	26615BETHEL, AK	212
213	26616KOTZEBUE, AK	213
214	26617NOME, AK	214
215	27401BARTER ISLAND, AK	215
216	27502BARROW, AK	216
217	93037COLORADO SPGS, COLO	217
218	93044ZUNI, N MEX	218
219	93045TRUTH OR CONS, N MEX	219
220	93058PUEBLO, COLO	220
221	93129CEDAR CITY, UTAH	221
222	93193FRESNO, CALIF	222

Table 5.1: Cont.

STATION	ID NUMBER
223 93721BALTIMORE, MD	223
224 93729CAPE HATTERAS, NC	224
225 93730ATLANTIC CITY, NJ	225
226 93738WASH-DULLES, VA	226
227 93739WALLOPS ISLAND, VA	227
228 93805TALLAHASSEE, FLA	228
229 93814CINCINNATI, OHIO	229
230 93815DAYTON, OHIO	230
231 93817EVANSVILLE, IND	231
232 93819INDIANAPOLIS, IND	232
233 93820LEXINGTON, KY	233
234 93821LOUISVILLE, KY	234
235 93822SPRINGFIELD, ILL	235
236 93987LUFKIN, TEX	236
237 93997RUSSELL, KANS	237
238 94008GLASGOW, MONT	238
239 94012HAVRE, MONT	239
240 94014WILLISTON, N DAK	240
241 94224ASTORIA, OREG	241
242 94240QUILLAYUTE, WASH	242
243 94702BRIDGEPORT, CONN	243
244 94725MASSENA, NY	244
245 94789NEW YORK, NY	245
246 94814HOUGHTON LAKE, MICH	246
247 94822ROCKFORD, ILL	247
248 94823PITTSBURGH, PA	248
249 94830TOLEDO, OHIO	249
250 94846CHICAGO, ILL	250
251 94847DETROIT, MICH	251
252 94849ALPENA, MICH	252
253 94860GRAND RAPIDS, MICH	253
254 94908DUBUQUE, IOWA	254
255 94910WATERLOO, IOWA	255

5.3 Approximate Analysis Based on Jorgensen et al. (31)

As previously stated, Jorgensen et al. (31) give the first two items of the necessary probabilistic information for 108 stations over the U.S.A. The locations of the stations are illustrated in Figure 5.2. The probabilistic information is given for the necessary 24-hour period and a reasonable discretization of rainfall depths. Lacking were the necessary joint probabilities, items 3 through 6 in Section 5.1. Since the original data set is unavailable, the missing probabilities are not attainable except through approximations.

For example, assuming complete independence would result in:

$$P[\text{rain in } i_1 \text{ and rain in } i_2] = P[\text{rain in } i_1]\, P[\text{rain in } i_2]$$

$$P[\text{no rain in } i_1 \text{ and no rain in } i_2]$$

$$= P[\text{no rain in } i_1]\ P[\text{no rain in } i_2]$$

$$P[\text{rain in } i_1 \text{ and no rain in } i_2] = P[\text{rain in } i_1]\, P[\text{no rain in } i_2]$$

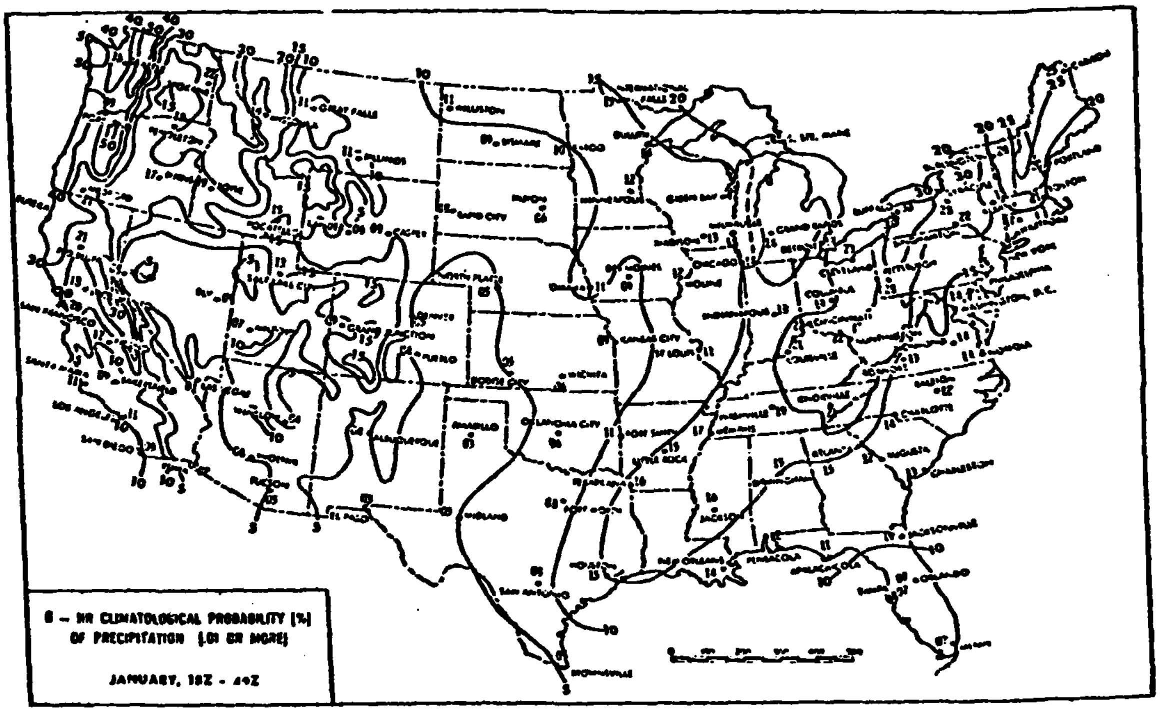


Figure 5.2: Locations of stations in Jorgensen's data set (31)

$P[\text{no rain in } i_1 \text{ and rain in } i_2] = P[\text{rain in } i_2] \; P[\text{no rain in } i_1]$

The above are fully defined by the Jorgensen, et.al., (31) results and readily obtained. They respresent a lower limit for the joint probabilities of events or no events. This is a minimum positive correlation case.

A maximum positive correlation case is obtained as follows. If N_{i_1} is the number of rainy events in i_1, N_{i_2} is the number of rainy events in i_2, and M the number of days in the record, then

$$P[\text{rain in } i_1 \text{ and rain in } i_2] \leq \frac{\text{Min}[N_{i_1}, N_{i_2}]}{M} = P_1 \qquad (5.2)$$

$$P[\text{no rain in } i_1 \text{ and no rain in } i_2] \leq \frac{\text{Min}[(M-N_{i_1}),(M-N_{i_2})]}{M} = P_2 \qquad (5.3)$$

For $N_{i_1} > N_{i_2}$

$$P[\text{rain in } i_1 \text{ and no rain in } i_2] \simeq \frac{N_{i_1} - N_{i_2}}{2M} = P_3 \qquad (5.4)$$

$P[\text{no rain in } i_1 \text{ and rain in } i_2] \simeq P_3$

For $N_{i_2} > N_{i_1}$

$$P[\text{rain in } i_2 \text{ and no rain in } i_1] \simeq \frac{N_{i_2} - N_{i_1}}{2M} = P_3 \qquad (5.5)$$

$$P[\text{rain in } i_1 \text{ and no rain in } i_2] \simeq P_3$$

If this approach were to be taken, a set of rules would have to be defined in order to decide when to use the independence or the maximum positive correlation case. One such set may be:

1) Stations east of the Rockies are independent of stations on or west of the Rockies.
2) Within the east and west regions independence will be tested by comparing mean storm depths over the 24 hour period.
3) Areas of doubt will be decided on the basis of qualitative mean storm track knowledge as given by Klein, (32).

A possible statistical test is the t test for two independent samples when variances are assumed equal. The hypothesis is that the difference of the true means is zero. The test is based on the statistic

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S_0 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)^{\frac{1}{2}}} \qquad (5.6)$$

where

$$S_o^2 = \frac{\sum_{i=1}^{n_1} (x_{1j} - \overline{x}_1) + \sum_{j=1}^{n_2} (x_{2j} - \overline{x}_2)}{n_1 + n_2 - 2} \tag{5.7}$$

The t value is compared with $t_{\alpha . n_1 + n_2 - 2}$, a t distributed variable with $n_1 + n_2 - 2$ degrees of freedom at an α level of significance.

In our case n_1 and n_2 are the number of rainfall days in a season at stations 1 and 2. The means, $\overline{x}_1$ and $\overline{x}_2$ are the average accumulations for a given time period. The combined variance can be computed as:

$$S_o^2 = \frac{n_1 \sum_{\ell=1}^{7} (x_{1\ell} - \overline{x}_1)^2 P[x_{1\ell}] + \sum_{\ell=1}^{7} (x_{2\ell} - \overline{x}_2)^2 P[x_{2\ell}] \cdot n_2}{n_1 + n_2 - 2}$$

$$= \frac{n_1 S_1^2 + n_2 S_2^2}{n_1 + n_2 - 2} \tag{5.8}$$

where $P[x_\ell]$ is the probability that if it rains the amount will be in the ℓth interval of the 7 defined by Jorgensen, et al (31).

Following are two examples.

For the spring months of March, April and May the average 24 hour accumulation in Kansas City, Mo., is 0.32 in. The corresponding average in Hartford, Conn., is 0.32 in. Are the two means statistically the same?

For an answer, use Equation 5.8, with $x_{1\ell}$ as the mid value of interval ℓ as defined by Jorgensen et al. (31), For Kansas City, $n_1 = 464$

$$S_1^2 = (.045 - .32)^2(1.00 - .62) + (.175 - .32)^2(.62 - .40)$$

$$+ (.375 - .32)^2(.4 - .22) + (.75 - .32)^2(.22 - .07)$$

$$+ (1.25 - .32)^2(.07 - .03) + (1.75 - .32)^2(.03 - .01)$$

$$+ (3 - .32)^2\ .01 = .21$$

For Hartford, $n_2 = 508$

$$S_2^2 = (.045 - .31)^2(1 - .64) + (.175 - .31)^2(.64 - .43)$$

$$+ (.375 - .31)^2(.43 - .21) + (.75 - .31)^2(.21 - .06)$$

$$+ (1.25 - .31)^2(.06 - .02) + (1.75 - .31)^2(.02 - .01)$$

$$+ (3 - .31)^2(.01) = .19$$

Therefore,

$$S_o^2 = \frac{464(.21) + 508(.19)}{464 + 508 - 2} = .17$$

The t statistic is

$$t = \frac{.32 - .31}{.41(\frac{1}{464} + \frac{1}{508})^{\frac{1}{2}}} = .38$$

The t distribution at $\alpha = .01$ for a 1 sided test is 2.326. The comparison indicates that our value is well inside that upper value indicating that we cannot reject the hypothesis that the means are the same.

For Louisville, Ky., $n_1 = 534$

$$S_1^2 = 0.23$$

when compared to Hartford

$$S_o^2 = \frac{534(.23) + 508(.19)}{534 + 508 - 2} = .21$$

and

$$t = \frac{.36 - .31}{.46(\frac{1}{534} + \frac{1}{508})^{\frac{1}{2}}} = 1.75$$

which indicates that the hypothesis of equal means is accepted at the 0.01 level but is rejected at the 0.05 level. This would be an unclear case, but it indicates relative power of the test.

5.4 Analysis of the TDL Raw Data Set

The most obvious approach to estimate the necessary joint probabilities is to analyze raw data. With the TDL data set, the record can be scanned to count the number of rainy days in any one station; the number of days with rain in a given depth interval ℓ in station i; the number of coincident wet days in any pair of stations; dry days in any pair of stations; and wet-dry in any pair of stations. Define these as N_i, $N_{1\ell}$, $N^1_{i_1 i_2}$, $N^2_{i_1 i_2}$, $N^3_{i_1 i_2}$ respectively. Then probability estimates are

$$P\,[\text{rain in } i_1 \text{ \underline{and} rain in } i_2] = \frac{N^1_{i_1 i_2}}{M} \tag{5.9}$$

$$P\,[\text{no rain in } i_1 \text{ and no rain in } i_2] = \frac{N^2_{i_1 i_2}}{M} \tag{5.10}$$

$$P\,[\text{rain in } i_1 \text{ and no rain in } i_2] = \frac{N^3_{i_1 i_2}}{M} \tag{5.11}$$

$$P\,[\text{no rain in } i_1 \text{ and rain } i_2] = 1 - \frac{(N^1_{i_1 i_2} + N^2_{i_1 i_2} + N^3_{i_1 i_2})}{M} \tag{5.12}$$

$$P[\text{rain in } i] = \frac{N_i}{M} \tag{5.13}$$

$$P[\text{no rain in } i] = 1 - \frac{N_i}{M} \tag{5.14}$$

$$P[\text{rainfall in depth interval } \ell \text{ and rainfall in } i] = \frac{N_{i\ell}}{M} \tag{5.15}$$

CHAPTER 6

Model Application and Case Study

6.0 *Introduction*

Appendix A provides an illustrative example of how the data analysis program works. This Chapter intends to illustrate the procedure with a somewhat more realistic case study. In doing so, the following objectives will be satisfied:

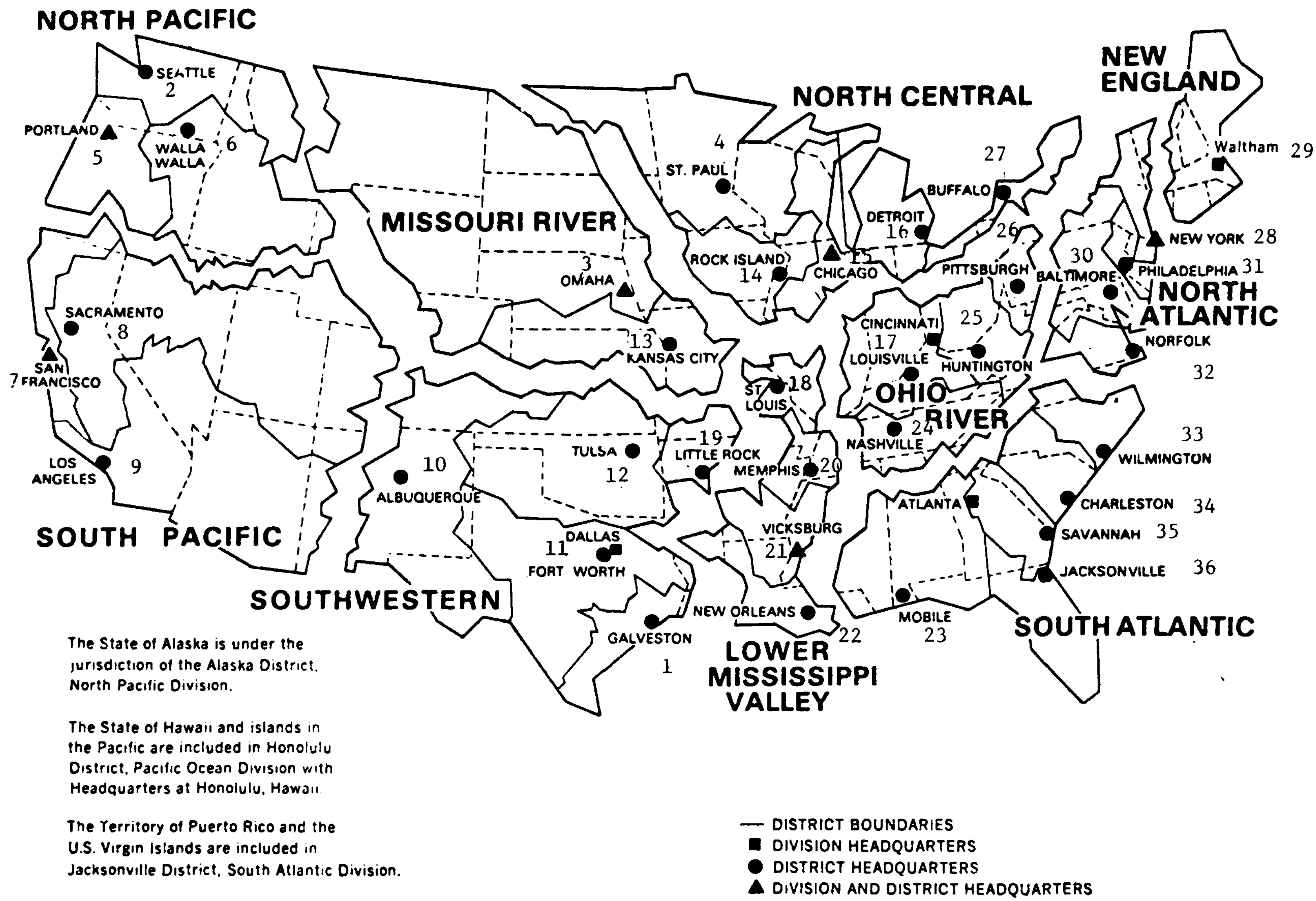
1. Discuss the preliminary steps necessary for network design. These include:
    a. computer coding the Corps of Engineers Districts map and precipitation stations locations.
    b. obtaining Thiessen areas for each station in each C. E. district in the nation.
    c. processing the precipitation data from the Techniques Development Laboratory.
2. Illustrate how to obtain transmission rates and relate them to rainfall totals.
3. Show how to evaluate hypothetical networks for various Corps of Engineers districts using a single satellite channel and adaptive random reporting.

6.1 Data Pre-Processing and Analysis

The purpose of this section is to review the key steps in the geographical and climatological data analysis required to generate the files for both prototype and production model application of DCPMAIN. Details of the character of the files needed for input to DCPMAIN are included in Appendix A. Details of the analysis models used to produce these files are presented in Appendix B.

Two distinct data sets and types of information are required by DCPMAIN. First is the geographical information -- the Thiessen areas and associated rainfall stations for candidate users. Because this project focuses on design of random reporting data collection networks for C of E users, the existing Corps district structure was used as the basis for identifying candidate users. There are currently 36 C of E districts, as shown in Figure 6.1, and each district was assigned a user number. User numbers are also displayed in Figure 6.1.

divisions and districts for civil works activities



The State of Alaska is under the jurisdiction of the Alaska District, North Pacific Division.

The State of Hawaii and islands in the Pacific are included in Honolulu District, Pacific Ocean Division with Headquarters at Honolulu, Hawaii.

The Territory of Puerto Rico and the U.S. Virgin Islands are included in Jacksonville District, South Atlantic Division.

Figure 6.1: Corps of Engineers Division and District Map

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The computation of Thiessen areas and associated rainfall stations required:

1. a digitized map to display the relative location of user boundaries; and
2. the location of rainfall data collection stations.

In order to construct the digitized district map, a 224 by 136 cell grid overlay of the "December 1970 Division and District Boundaries" map of Corps districts was developed. Each point on the grid was assigned to a Corps district, or a "null" district outside of the area of interest. This assignment was accomplished using program CAPPER which takes as input data on district boundary coordinates. The resultant digital map was verified and stored in File MAP. A display of the output map is shown as Figure 6.2. The information on rain gauge station locations was developed from NWS publications and TDL data sheets. The longitude and latitude locations were transformed to grid locations for input to Program MAPPER, the program for computation of Thiessen areas. For each of the 36 user areas, the rainfall stations influencing the area, and the fraction of total district area which each station influenced, were stored in FIL1, the geographical information file, generated by program MAPPER.

Figure 6.2: Digitized District Map, horizontal and vertical scales are distorted

The second key type of information required is climatological data -- specifically information on rainfall throughout the conterminous United States. As noted in Section 5.2.1, the NWS TDL data set of rainfall data at 6-hour intervals for 255 stations, was selected as the most suitable source for climatological data analysis. This data for 9 years from October 1, 1972, through September 30, 1981, was obtained on magnetic tape.

The data were analyzed using Program ZAPPER to evaluate numbers of events, and TAPPER to convert these numbers to relative frequencies of occurrence of events. The analysis was conducted for 4 seasons as follows:

Season	Months
1	December, January, February
2	March, April, May
3	June, July, August
4	September, October, November

For each season, two types of information were generated:

1. A station file containing information on probabilities of rainfall for various depth classes for each of the 255 rainfall stations; and
2. A cross or paired station file containing information on probabilities of joint occurrence of rainfall between each of the possible pairs of rainfall stations.

These data provide the climatological input to the analysis of random reporting data collection platform networks.

The type of data needed have been described extensively in Chapter 5. For each station, the probabilities of events in the following depth intervals and under the following conditions are obtained:

a. 0.00 - 0.01 inches

b. 0.01 - 0.50 inches, given rain

c. 0.50 - 1.00 inches, given rain

d. 1.00 - 1.25 inches, given rain

e. 1.25 - 1.50 inches, given rain

f. 1.50 - 2.00 inches, given rain

g. 2.00 - 3.01 inches, given rain

h. 3.00+ inches, given rain.

In addition for each pair of stations the following probabilities are obtained:

a. no rainfall at i and no rainfall at j

b. no rainfall at i and rainfall at j

c. rainfall at i and no rainfall at j

d. rainfall at i and rainfall at j.

The station data are stored in files F2S1, F2S2, F2S3, and F2S4. The cross station or paired station data are stored in files F3S1, F3S2, F3S3, and F3S4.

This completes the overview of the geographical and climatological data processing and analysis. The sections that follow present first a discussion of determination of reporting rates, and then a review of the prototype model application.

6.2 Determining Reporting Rates

Recall from Chapter 2 that most DCP's set their message transmision rate according to an algorithm of the form:

RATE = MAX[BASE RATE, (A*CHANGE IN PARAMETER)]

For example, the New England Division has suggested the following parameters for a typical station (Jewett City, CT) in their area:

For flows less than 8080 cfs, the base rate is 1 message every 12 hours (2.31×10^{-5} mess/sec). For flows between 8080 and 14450 cfs the base rate is 1 message every 2 hours (1.39×10^{-5} mess/sec). For flows above 14450 cfs the base rate is 1 mesage every 30 minutes (5.55×10^{-4} mess/sec). Parameter A is 3.33×10^{-2} and a sample is taken every 1800 seconds (0.5 hour) to check for parameter changes. In summary the reporting algorithm is:

$$\text{RATE} = \max \left[\begin{array}{l} 2.31 \times 10^{-5} \\ \quad\text{or} \\ 1.39 \times 10^{-4}, \quad 3.33 \times 10^{-2} \left(\frac{100\Delta x}{1800}\right) \\ \quad\text{or} \\ 5.55 \times 10^{-4} \end{array} \right]$$

where Δx is the change in stage in the last half hour, in feet. Figure 6.3 shows how the base rates plot versus discharge. The resulting step function is shown in dashes.

To get an idea of what would be the maximum transmission rate at Jewett City, we studied the largest flood on record [42]. In August 20,

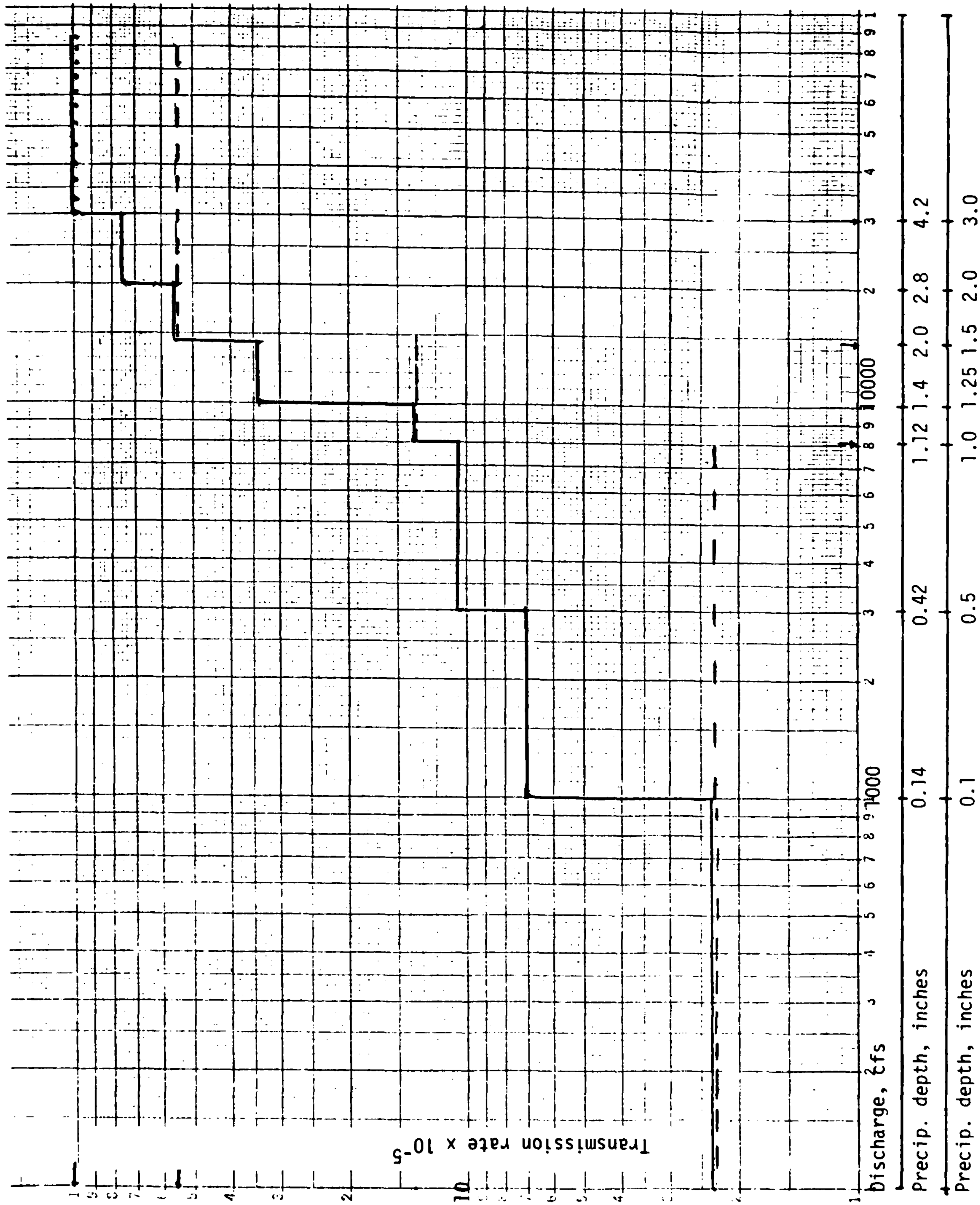

Figure 6.3: Determination of precipitation depth intervals

1955 the peak discharge was recorded at 40,700 cfs. Previous to that event the largest flood had been 29,200 cfs. During the August 20, 1955, flood, the largest observed change of state in one hour was 1.1 feet which approximately gives a 0.5 ft. change in half an hour. According to the reporting rate algorithm this would have led to a message about every 15 minutes (0.11×10^{-2} mess/sec). This rate is plotted with dots in Figure 6.3, starting at 30,000 cfs (the second largest flood in the record).

The eight reporting rates needed in our analysis (Chapter 4) correspond to a <u>peak</u> reporting rate achieved during a rain-flood <u>event</u>. Since all stations within a user utilize the same set of reporting rates, it is assumed that although different basins and streamflow stations within a user will achieve different peaks, the user would want similar time resolution at the peak for all sites.

It is then reasonable to state that the eight reporting rates we are looking for should lie between the lowest dash line and the dotted line in Figure 6.3. The rates and discharge break points are determined by arbitrarily (but reasonably) dividing the ordinate and abscissa between dash and dotted lines in Figure 6.3, resulting in the step function shown in solid lines. Notice that more sampling resolution was added in the lower discharge ranges, which are the most common and were somewhat sparse in reporting frequency. The abscissa in the Figure now represents peak discharge. It must be translated to rainfall accumulation in 24 hours, according to the limitations of our analysis. In following the above procedure it is implicitly assumed that: a) large rates of change in stage are associated with large floods, and b) that all DCPs within the influence of a precipitation station peak simultaneously. The first assumption is reasonable and the second will lead to conservative results in terms of number of DCP's in a channel.

There are many existing methods to translate peak discharge to total rainfall accumulation. A possibility is to use the techniques suggested by the Soil Conservation Service (43),

$$Q_p = \frac{484\ A\ P_E}{t_p} \tag{6.1}$$

where Q_p is peak discharge in cfs; A is basin area in square miles; P_E is effective total precipitation (runoff) in inches, and t_p is time to peak discharge from the beginning of rainfall. This time can be expressed as (43)

$$t_p = \frac{t_r}{2} + t_\ell \tag{6.2}$$

where t_r is the storm duration (hours) and t_ℓ is a "lag" time, related to the invariant time of concentration, defined as the time in hours from storm centroid to peak discharge. The effective precipitation or runoff (P_E) can be reasonably obtained for any basin using the Soil Conservation Service "curve number" concept or using traditional antecedant precipitation index coaxial solutions. The lag time (or the time of concentration) is again generally available or reasonably estimated.

For the sake of this example we "calibrated" Equation 6.1 to the August 20, 1955, flood. From the literature (42) t_ℓ was estimated as 72 hours; total gross rainfall over the period as 10.5 inches; and a runoff coefficient as 0.6. This leads to P_E = 6.3 inches (10.5 x 0.6). The tributary area to Jewett City station is 711 mi^2. Q_p was seen to be 40700 cfs. Solving Equation 6.1 results in time to peak (t_p) of 53 hours. Using this value in 6.2 yields a lag time, t_ℓ, of 17 hours.

Having t_ℓ it is now possible to associate each Q_p in Figure 6.1 with a gross 24-hour precipitation accumulation (still assuming a runoff coefficient of 0.6). The Equation is simply

$$P = \frac{(\frac{24}{2} + 17) \cdot Q_p}{(484)(711)(0.6)} = \frac{Q_p}{7119.8} \qquad (6.3)$$

The results are indicated in the second abscissa in Figure 6.3. From them, reasonable breaking points (or rainfall intervals can be defined for our analysis. They are shown in the third abscissa in the Figure. In summary, the reporting rate algorithm for Jewett City is:

i	b_{ij} (mess/sec)	rainfall interval (inches)
1	2.315×10^{-5}	0 - 0.01
2	7.0×10^{-5}	0.01 - 0.5
3	10.5×10^{-5}	0.5 - 1.0
4	13.89×10^{-5}	1.0 - 1.25
5	34.0×10^{-5}	1.25 - 1.5
6	55.5×10^{5}	1.5 - 2.0
7	75.0×10^{-5}	2.0 - 3.0
8	111.0×10^{-5}	> 3.0

The above reporting rates will be assumed for the New England Division Corps of Engineers in our illustrative example. The rainfall intervals correspond to the ones used in our analysis of the Techniques Development Laboratory data.

6.3 Case Study Results

In practice each district should follow an exercise similar to the one outlined above for the New England Division. For the purposes of our hypothetical case study, the reporting rates schedule for each district studied will be the same, equal to that computed for the New England Division. It will also be assumed that each district will have 80 DCPs and message duration of 3 seconds. The unit load limitation will be set at 5 seconds per station. The season studied will be the months of June, July and August, season 3, and 3 repetitions of a message are allowed.

In the first experiment, New York (28), Buffalo (27), Baltimore (30) and Pittsburgh (26) districts are assumed operating in one channel. In a second experiment we consider New York (28), Cincinnati (17), Tulsa (12) and Sacramento (8). The numbers in parenthesis correspond to the identification numbers in the computer files containing our digitized map. Table 6.1 gives the input data sequence for both runs.

Given the experiments design, any differences in results would be solely due to differences in precipitation statistics of the various group of users. It would be expected, and can be confirmed from statistics file F3S3 that Case 1 users would show much higher correlations of events than Case 2 users. This should lead to differences in reliability levels.

Case 1 results indicate that individual users have little problems satisfying unit loads or reliability criteria. Also notice the similarity of the basic statistics of the users, means and variances of reporting rates. The reliability of successful message transmission for all users in Case 1 together is 0.8944. Remember, this implies that about 11 percent of the time less than 95% successful transmissions are achieved.

TABLE 6.1

Input Data Sequence for Hypothetical Case Studies

Card	Column 2	10	20	30	40	50	60	70	80
<u>Case</u> 1									
1		4							
2a		28	80						
3a		2.315E-05	7.0E-05	10.5E-05	13.89E-05	34.0E-05	55.5E-05	75.0E-05	111.0E-05
2b		27	80						
3b	as 3a								
2c		30	80						
3c	as 3a								
2d		26	80						
3d	as 3a								
4		3							
5		5.0							
6		3							
7		3.0							
<u>Case</u> 2	(all cards the same except)								
2b		16	80						
2c		11	80						
2d		7	80						

Case 2 results show much larger differences in individual stations statistics. Nevertheless, individual users again have little trouble satisfying unit load and reliability criteria. In contrast to Case 1 the group performance is much better showing a 0.9773 probability of meeting the 95% reliability criteria. This implies that failure to satisfy this level of reliability occurs only 3% of the time versus 11% in Case 1.

It seems that climatic effects can be fairly important in network design. The user of this system can experiment with various configurations of users looking to maximize performance and number of users per channel.

Cases 1 and 2 Results

```
ST80

ECHO PRINT OF USER INPUT DECK

TOTAL NUMBER OF USERS (NUSER) =          4

USER ID NUMBER =          28 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

USER ID NUMBER =          27 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

USER ID NUMBER =          30 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

USER ID NUMBER =          26 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

UNIT LOADING FACTOR =       5.00

MESSAGE REPITITION RATE =          3

MESSAGE DURATION =      3.00

           LOCAL DESIGN
```

USER ID NUMBER = 28 NUMBER OF PLATFORMS = 80

HLAMJ VARLJ

0.50173E -4 0.12767E -8

LOCAL DESIGN

USER ID NUMBER = 27 NUMBER OF PLATFORMS = 80

HLAMJ VARLJ

0.56782E -4 0.58908E -9

LOCAL DESIGN

USER ID NUMBER = 30 NUMBER OF PLATFORMS = 80

HLAMJ VARLJ

0.50984E -4 0.12395E -8

LOCAL DESIGN

USER ID NUMBER = 26 NUMBER OF PLATFORMS = 80

HLAMJ VARLJ

0.56808E -4 0.74062E -9

NATIONAL DESIGN

BLAMDA = 0.53608E -4 VARLB = 0.89065E -9

LOCAL DESIGN

USER ID NUMBER = 28 NUMBER OF PLATFORMS = 80

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY 0.9981

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34788E -3

IT IS SATISFIED WITH PROBABILITY 0.9999

LOCAL DESIGN

USER ID NUMBER = 27 NUMBER OF PLATFORMS = 80

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY 0.9999

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34788E -3

IT IS SATISFIED WITH PROBABILITY 0.9999

LOCAL DESIGN

USER ID NUMBER = 30 NUMBER OF PLATFORMS = 80

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY   0.9881

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34722E -3

IT IS SATISFIED WITH PROBABILITY   0.9999

LOCAL DESIGN

USER ID NUMBER =   26   NUMBER OF PLATFORMS =   30

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY   0.9998

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34722E -3

IT IS SATISFIED WITH PROBABILITY   0.9999

NATIONAL DESIGN

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.86806E -4

IT IS SATISFIED WITH PROBABILITY   0.8944

```
$T48

ECHO PRINT OF USER INPUT DECK

TOTAL NUMBER OF USERS (NUSER) =          4

USER ID NUMBER =          28 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

USER ID NUMBER =          16 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

USER ID NUMBER =          11 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

USER ID NUMBER =           7 NUMBER OF PLATFORMS =          80

BASE REPORTING RATES
0.23150E -4  0.70000E -4  0.10500E -3  0.13890E -3  0.34000E -3  0.55500E -3  0.75000E -3  0.11100E -2

UNIT LOADING FACTOR =       5.00

MESSAGE REPITITION RATE =          3

MESSAGE DURATION =       3.00


         LOCAL DESIGN
```

USER ID NUMBER = 28 NUMBER OF PLATFORMS = 80

HLAMJ	VARLJ
0.50173E -4	0.12767E -8

LOCAL DESIGN

USER ID NUMBER = 16 NUMBER OF PLATFORMS = 80

HLAMJ	VARLJ
0.52936E -4	0.54641E -9

LOCAL DESIGN

USER ID NUMBER = 11 NUMBER OF PLATFORMS = 80

HLAMJ	VARLJ
0.36404E -4	0.95738E -9

LOCAL DESIGN

USER ID NUMBER = 7 NUMBER OF PLATFORMS = 80

HLAMJ	VARLJ
0.47950E -4	0.15714E -8

NATIONAL DESIGN

BLAMDA = 0.46868E -4 VARLB = 0.38328E -9

LOCAL DESIGN

USER ID NUMBER = 28 NUMBER OF PLATFORMS = 30

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY 0.9981

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34722E -3

IT IS SATISFIED WITH PROBABILITY 0.9999

LOCAL DESIGN

USER ID NUMBER = 16 NUMBER OF PLATFORMS = 30

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY 0.9999

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34722E -3

IT IS SATISFIED WITH PROBABILITY 0.9998

LOCAL DESIGN

USER ID NUMBER = 11 NUMBER OF PLATFORMS = 30

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY 0.9999

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34722E -3

IT IS SATISFIED WITH PROBABILITY 0.9998

LOCAL DESIGN

USER ID NUMBER = 7 NUMBER OF PLATFORMS = 80

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS 0.15432E -3

IT IS SATISFIED WITH PROBABILITY 0.9960

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.34722E -3

IT IS SATISFIED WITH PROBABILITY 0.9999

NATIONAL DESIGN

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.86806E -4

IT IS SATISFIED WITH PROBABILITY 0.9773

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Appendix A

DCPMAIN USERS MANUAL

A.1 Introduction

DCPMAIN is a statistical algorithm written in standard Fortran IV, for the analysis of adaptive random reporting data collection networks. Details of the algorithm are given in Chapter 4 of this report. This software is intended to serve as a screening tool for the design and evaluation of DCP networks adaptively responding to spatially and time varying climate. The subsections which follow will provide users of DCPMAIN with the information necessary for its use.

Several modeling assumptions were made during program development and are summarized below:

1. A "user" is defined as a Corps of Engineers District or any other non-overlapping geographical unit.
2. All users have the same message length and will strive for message reliability using repetition Method 2 as described in the "Users Guide for Random Reporting (6)". The number of repetitions is taken to be at least 3, the same for all users. The number of repetitions is a user controlled parameter.
3. All stations within a user have the same adaptive reporting rate algorithm. This implies the same possible reporting rates. Different users can have different parameters.

4. Trading of unit loads between users will not be allowed.
5. Each user will attempt to use up to their available unit loads. A unit load is presently defined as 120 sec. per day per station or 5 sec. per hour per station, whatever is limiting over the daily or hourly intervals. Nevertheless, this is a user controlled parameter.

A.2 Model Description

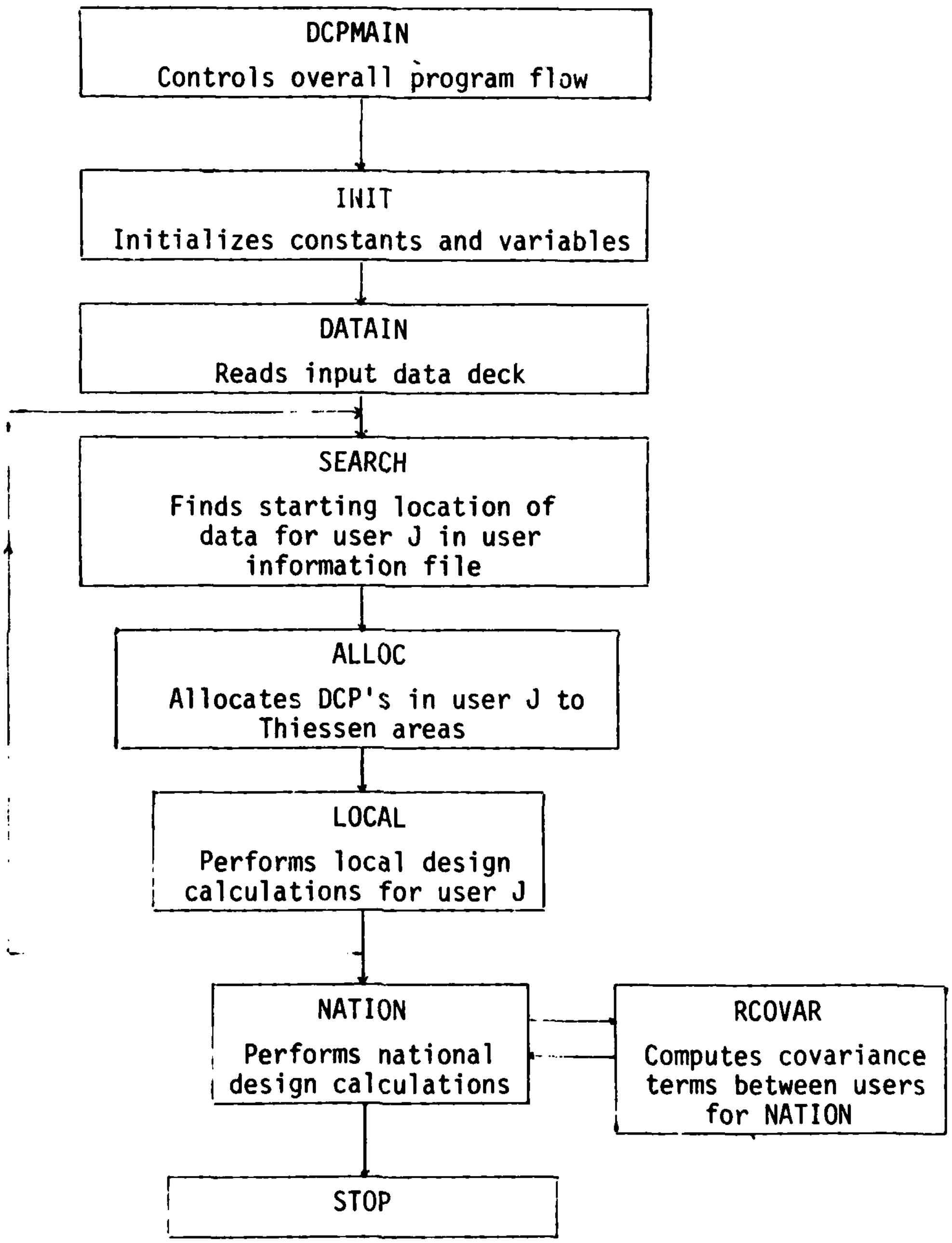
DCPMAIN evaluates performance of adaptive random reporting data collection platforms operating on a single GOES channel at both local and national (or regional) levels. The model first evaluates DCP performance at the local or user level. Following this, calculations are made to assess network performance on a nation-wide or channel-wide basis. The general structure of DCPMAIN is illustrated in the logic flow chart of Figure A.1.

Due to the seasonal variations in the climatology of the continental U.S., DCPMAIN has been designed to operate on a four season basis. The main input is probabilistic rainfall information over 24 hour periods within seven depth intervals. The intervals are user defined in program ZAPPER. Data analysis was performed in this project using the following intervals: 0.0-0.01, 0.01-0.5, 0.5-1.0, 1.0-1.25, 1.25-1.5 1.5-2.0, 2.0-3.0 and greater than 3.0 inches.

A brief description of individual subroutines follows.

Figure A.1

DCPMAIN LOGIC STRUCTURE



DCPMAIN

DCPMAIN is the main or controlling routine for the DCPMAIN program. It controls the logical flow of data through the model, from entry of input data to the printing of final results. All required data files are initialized and opened as specified in the input data stream. Evaluation of the probability of user compliance of unit load limitations and of the probability of achieving 95% (or larger) message reception reliability at the local and national levels is done in DCPMAIN following the concepts presented in Chapter 4.

SUBROUTINE INIT

Subroutine INIT initializes all major arrays and variables required during program execution. In addition, program default values are set. Defaulted are units (or channels) numbers for input/output operations and variable ICON1 which is set equal to the number of stations in the meteorological records analyzed by program ZAPPER (see Appendix B). It is presently defaulted at 255.

SUBROUTINE DATAIN

Subroutine DATAIN reads and processes the input data deck for simulation and echo prints the input stream.

SUBROUTINE SEARCH

Subroutine SEARCH reads and locates the starting position of data stored in the user information file (see next section) for a specific user. Users must be uniquely identified by numbers.

SUBROUTINE ALLOC

Subroutine ALLOC allocates DCP's in a given user to precipitation stations within the user. The number of stations within a user are assumed uniformly distributed and assigned to precipitation stations in proportion to Thiessen areas of a station within a user. The procedure is described in Section 5.1 (Equation 5.1) of the main report. In addition, a check is performed to ensure that the number of stations and associated areas have been properly recorded in the user information file.

SUBROUTINE LOCAL

Subroutine LOCAL performs the bulk of the calculations required to evaluate local or user design criteria.

The subroutine computes:

a) The mean reporting rate at a station, $\hat{\lambda}_{ij}$, as described by Equation 4.7.

b) The variance of the reporting rate, $\mathrm{var}[\lambda_{ij}]$, as described by Equation 4.9.

c) The covariance between all stations within a user, Equation 4.10.

d) The mean station reporting rate for a user, $\hat{\lambda}_j$, as in Equation 4.6.

e) The variance of the mean station reporting rate, $\mathrm{var}[\bar{\lambda}_j]$, as in Equation 4.8.

The program assumes that all DCPs assigned by ALLOC to a given precipitation station have the statistical properties of that station. Therefore, the code avoids summing over all DCP as in Equations 4.6 and 4.8, and exploits the fact that many of the terms in those equations are operationally the same.

All covariance terms, also those calculated for the national design (subroutine NATION) correspond to Equation 4.10. Nevertheless, the program computes them using an equivalent but more efficient mathematical formulation. Term 1 in Equation 4.10 remains the same in the program. Terms 2 through 4 are computed using:

Term 2:

$$(b_{1j} - \hat{\lambda}_{i_1 j})P[\text{rain in } i_2 \text{ and not in } i_1].$$

$$\{ \sum_{\ell=2}^{8} b_{\ell j} P[\text{rains in interval } \ell \text{ at } i_2] - \hat{\lambda}_{i_2 j} \}$$

Term 3

$$(b_{1j} - \hat{\lambda}_{i_2 j}) P[\text{rain in } i_1 \text{ and not in } i_2].$$

$$\{ \sum_{\ell=2}^{8} b_{\ell j} P[\text{rains in interval } \ell \text{ at } i_1] - \hat{\lambda}_{i_1 j} \}$$

Term 4

$$P[\text{rains in } i_1 \text{ and } i_2] \cdot \{ [\sum_{\ell_1=2}^{8} b_{\ell_1 j} P[\text{rain in interval } \ell_1 \text{ in } i_1] - \hat{\lambda}_{i_1 j}]$$

$$\cdot [\sum_{\ell_2=2}^{8} b_{\ell_2 j} P[\text{rain in interval } \ell_2 \text{ in } i_2] - \hat{\lambda}_{i_2 j}] \}$$

SUBROUTINE NATION

Subroutine NATION completes calculations at the national level, utilizing the results obtained from subroutine LOCAL and station covariance terms between users computed in Subroutine RCOVAR. Equations 4.14 through 4.16 are used. Final output from subroutine NATION includes the mean national DCP reporting rate and its variance.

SUBROUTINE RCOVAR

Subroutine RCOVAR calculates covariance terms between stations in different users. Its results are used by subroutine NATION. The algorithm used to compute covariances is identical to that of subroutine LOCAL.

A.3 Program Data Requirements

In order to run DCPMAIN, three data base files are required, as well as an input data deck (in disk file). The contents of each of these files and file formats will be presented in the sections to follow.

A.3.1 User Information File

The user information file, FIL1, is a random access file generated by program MAPPER (see Appendix B). Each user is allocated 51 records for the storage of a user identification number in the first record followed by 25 records containing paired data entries composed of a precipitation station identification number and the percent areal coverage of that station within the user.

This file begins in record zero and may contain data for up to 1260 individual users. Nevertheless, the analysis is presently limited to 36 users. The user identification number is stored in fixed I10 format and, therefore, must be an integer value ending in column 10. Columns 21 through 30 should contain 0.0.

Following the user identification number record, 25 records are reserved for storage of precipitation station identification numbers and fractional areal coverage of that station within a given user. These values are stored in fixed format beginning with the precipitation station identification number, ending in column 10, and the fractional areal coverage of that station located in columns 21 through 30. The fractional areal coverage values should contain a decimal point and, when summed for a given user should equal 1.00. Users with fewer than 25 paired station values must contain records with zero values for both the station identification number and percent areal coverage up to the 25th record.

A sample user information file for a 3 user case (with a 6 station limitation) and only 26 records per user is illustrated in Table A.1.

A.3.2 Precipitation Station Probability Files

The precipitation station probability files are random access files generated by program ZAPPER (Appendix B). Four files should be available for use containing seasonal information. These files are named F2S1, F2S2, F2S3, and, F2S4 representing "file 2, season 1" through "file 2, season 4." Since runs are made on a seasonal basis, only one of the above files is required for an individual simulation. This file must correspond to the season of interest.

Each record contains a precipitation station identification number, a season flag value, the probability of no precipitation for that station, and, seven probabilities of precipitation within the given depth intervals (given that it rains). The records are arranged in sequential order by precipitation station identification number, beginning with record one and ending with record 255 (or the number of precipitation stations analyzed by program ZAPPER).

Table A.1

Sample User Information File, FIL1

cc	10	30	10	30
	100	00000	0	00000
	1	.25000	0	00000
	2	.15000	200	00000
	4	.25000	3	.15000
	6	.35000	4	.0750
	0	00000	5	.70000
	0	00000	6	.0750
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	0	00000	0	00000
	500	00000	0	00000
	2	.40000	0	00000
	3	.60000	0	00000
	0	00000	0	00000
	0	00000		
	0	00000		
	0	00000		
	0	00000		
	0	00000		
	0	00000		
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	0	00000		
	0	00000		
	0	00000		
	0	00000		
	0	00000		
	0	00000		

Data values are stored in fixed format with an integer station identification number ending in column 10, an integer season flag value (i.e., 1, 2, 3, or 4) located in column 20, and, the eight probability values located in columns 21 through 100. Probability values are stored as real values to three significant digits in fields of 10 columns each. As a check, the sum of the seven depth interval probabilities should equal 1.0.

A sample precipitation station probability file for season 1 is shown in Table A.2, again for a 3 user, six climatological stations case.

A.3.3 Conditional Probability Paired Station File

The conditional probability paired station files are random access files generated by program ZAPPER. As with the precipitation station probability files, four files should be available, by season. These files are called F3S1, F3S2, F3S3 and, F3S4 corresponding to "file 3, season 1," etc. Here again, only one of the above files is required for an individual run for the season of interest.

Each record of the conditional probability paired station file contains two integer station identification numbers followed by an integer season flag value and each of the following probabilities: P[no rain in station i_1, and no rain in station i_2]; P[no rain in station i_1, and rain in station i_2]; P[rain in station i_1, and no rain in station i_2]; P[rain in station i_1, and rain in station i_2].

Data values are stored in fixed format beginning in record zero. Station identification numbers end in columns

Table A.2
Sample Precipitation Station Probability File, F2S1

cc	10	20	30	40	50	60	70	80	90	100
rec 0 →	1	1	0.700	0.300	0.200	0.200	0.100	0.100	0.100	0.000
	2	1	0.600	0.100	0.300	0.400	0.100	0.100	0.000	0.000
	3	1	0.400	0.100	0.200	0.300	0.300	0.100	0.000	0.000
	4	1	0.600	0.100	0.200	0.200	0.300	0.100	0.100	0.000
	5	1	0.500	0.100	0.100	0.200	0.300	0.200	0.000	0.100
	6	1	0.600	0.100	0.100	0.100	0.200	0.300	0.100	0.100

Table A.3
Sample Conditional Probability Paired Station File, F3S1

cc	10	20	30	40	50	60	70
rec 0 →	1	2	1	0.420	0.180	0.280	0.120
	1	3	1	0.280	0.120	0.420	0.180
	1	4	1	0.420	0.180	0.280	0.120
	1	5	1	0.350	0.150	0.350	0.150
	1	6	1	0.420	0.180	0.280	0.120
	2	3	1	0.240	0.160	0.360	0.240
	2	4	1	0.360	0.240	0.240	0.160
	2	5	1	0.300	0.200	0.300	0.200
	2	6	1	0.360	0.240	0.240	0.160
	3	4	1	0.240	0.360	0.160	0.240
	3	5	1	0.200	0.300	0.200	0.300
	3	6	1	0.240	0.360	0.160	0.240
	4	5	1	0.300	0.200	0.300	0.200
	4	6	1	0.360	0.240	0.240	0.160
	5	6	1	0.300	0.300	0.200	0.200

Table A.4
Sample Input File, FILO

```
        3
      100         15
9.259E-05 1.389E-04 5.556E-04 8.333E-04 1.111E-03 1.389E-03 1.667E-03 2.222E-03
      200         10
6.944E-05 1.389E-04 2.778E-04 5.556E-04 8.333E-04 1.389E-03 1.667E-03 1.944E-03
      500          5
6.944E-05 1.389E-04 2.778E-04 5.556E-04 1.111E-03 1.389E-03 1.944E-03 2.500E-03
        1
      5.0
        3
      2.0
```

10 and 20 for stations i_1 and i_2, respectively. The season flag value (i.e., 1, 2, 3, or 4) is located in column 30 and joint station probabilities are located in columns 31 through 70. Each probability value is stored as a real value to three significant figures in fields of 10 columns each. The paired station values are ordered as shown in Table A.3, again for a limited example of 3 user, 6 stations. Probabilities in each record should sum to 1.0.

A.3.4 Data Input Deck

The data input deck for DCPMAIN, file FILØ, is a sequential file read by subroutine DATAIN. All data values are in entered in fixed format. Each of the data cards required is described below.

Card 1: The first card of the data input deck contains the number of users for the simulation. The current configuration of the program allows for a maximum of 36 users per simulation. This card is read in I10 format, and, therefore, should be right justified ending in column 10.

Cards 2 and 3: The next set of cards contains the required input information for user one, the first of which, card 2, contains two integer values. The first value is the user identification number for user one. This must correspond to a user identification number in the user information file, or execution will be terminated. The second value on card 2 is the number of DCP's assigned to user one. This should be right justified and end in column 20.

Card 3 contains the eight base reporting rates for user one (see Chapter 4). These are entered in units of transmissions per second beginning with the transmission rate during dry periods and ending with the maximum transmission rate for rainfall accumulations greater than 3.0 inches. All values are entered in fields of 10 columns leaving the first column blank, i.e., 8(1X,E9.7) format. Therefore, data entries should be right-justified and end in columns 10, 20, 30 ... and, 80.

If multiple users are to be simulated, Cards 2 and 3 are simply repeated with appropriate values for each user. The total number of user groups (i.e., Card 2 and Card 3 combinations) must, however, correspond to the number of users specified on Card 1 of the input data deck.

Card 4: Card 4 contains the season flag value for the simulation run. This is read in fixed format and must be located in column 10. Feasible values range from 1 to 4 and correspond to season 1, season 2, season 3 and season 4 of the precipitation station probability files and conditional probability paired station files, respectively.

Card 5: Card 5 of the input stream contains the maximum transmission duration, in seconds per hour, specifying a unit load per DCP. Currently, NESS has defined a unit load as five seconds per hour per DCP. This value is entered in columns 1 through 10 and must contain a decimal point. This is assumed constant for all users.

Card 6: Card 6 contains the number of transmission repetitions for each DCP. This is an integer value read in I10 format, and, therefore, must be right-justified ending in column 10. Generally three repetitions correspond to a desired .95 probability of successful transmission. Five repetitions correspond to .99 probability of successful transmission.

Card 7: The final card in the input stream, Card 7, contains the message transmission duration in seconds. This is a real value entered in columns 1 through 10 and must contain a decimal point. Transmission durations are also assumed constant for all DCP's.

A sample input data stream for three users is listed in Table A.4. For user 100, simulation will be performed for a total of 15 platforms. Users 200 and 500 contain 10 and 5 platforms each. The season selected is season 1. A unit load has been defined as 5 transmissions per hour per user with a transmission duration of 2.0 seconds and 3 repetitions per message.

A.4 Program Output

Results from the program are best illustrated with a small example. Tables A.1 through A.4 correspond to input data of a hypothetical case study where the performance of 3 users in a single channel is being evaluated. Figure A.2 is a schematic diagram of the 3 users configuration, with available climatological stations, shown by a triangle and an approximately uniformly distributed DCP shown by circles.

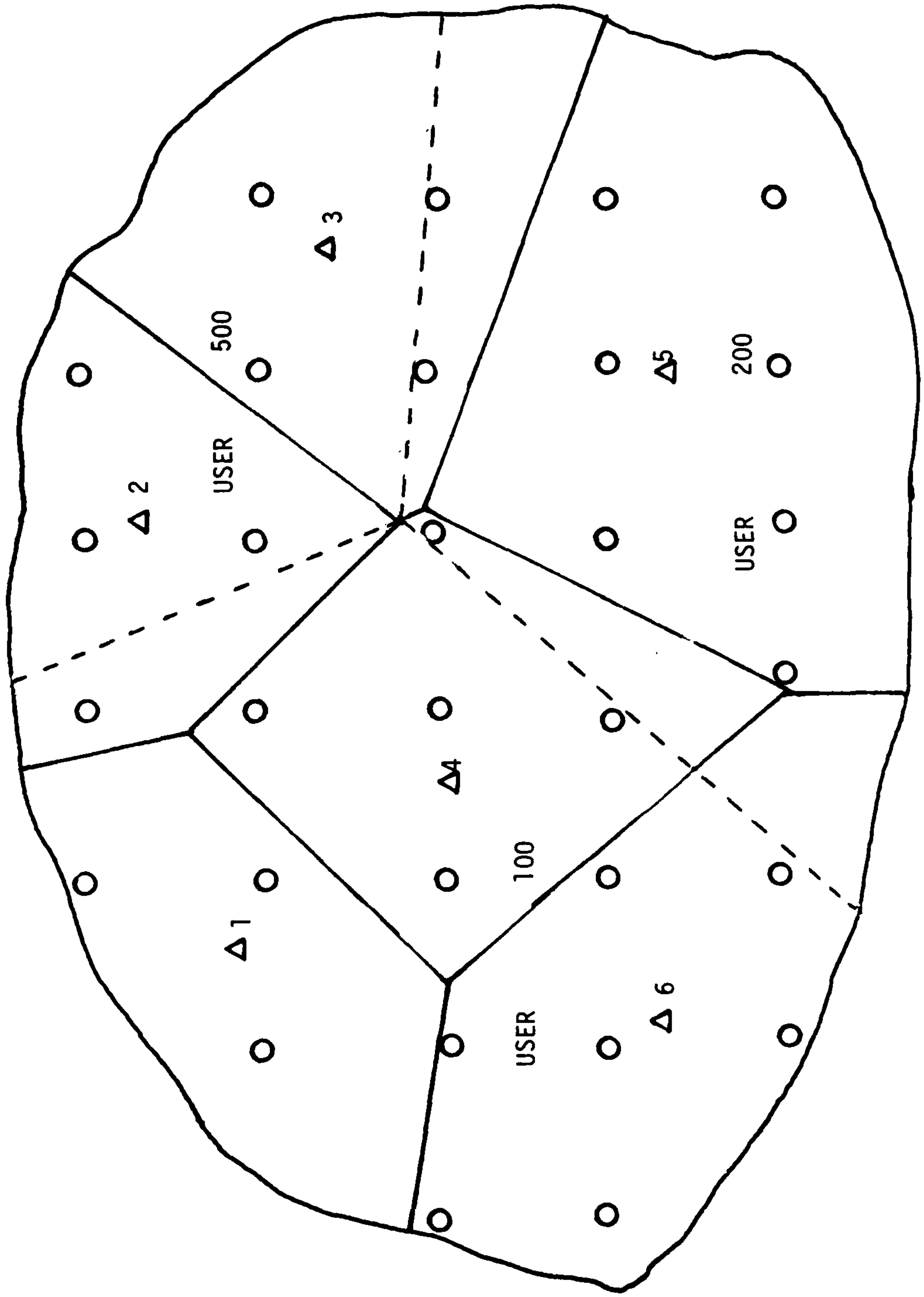


Figure A.2: Schematic diagram of sample problem

The output follows in Table A.5. First the user information input is echo-printed. It indicates the number of users, their identification numbers, the number of DCP's per user and the 8 reporting rates of each user. Also given is the unit loading factor in seconds per hour; the message repetition rate; and the message duration in seconds.

Results of the local design follow. For each user, the mean reporting rate per station and the variance of the reporting rate are given. The mean has units of messages per second. The variance has the same units squared. The differences in means and variances are due to different reporting rates, different climatological probabilities and different number of DCP's.

After all users statistics are given, the program outputs the mean reporting rate per station for all users in the channel (the "nation") and the variance of the reporting rate of the nation.

Finally, design criteria is output for all users and the nation. For example, at the local level, user 200 with 10 stations satisfies the unit load limitation approximately 29% of the time (violates it 71% of the time). Nevertheless, 95% reliability (since 3 repetitions are made) is achieved nearly 100% of the time. Also given for each user is the maximum deterministic reporting rate allowed to be within the unit load requirement 100% of the time, Equation 4.11; and the rate that would be required as an absolute maximum to have 95% or more reliability of message reception 100% of the time, Equation 4.12.

Similar information is given for the national level. In the example 95% reliability of message reception is achieved nearly 100% of the time at the national level.

Table A.5

Sample Output of DCPMAIN

```
8T8$

ECHO PRINT OF USER INPUT DECK

TOTAL NUMBER OF USERS (NUSER) =          3

USER ID NUMBER =        100 NUMBER OF PLATFORMS =        15

BASE REPORTING RATES
0.92590E -4  0.13890E -3  0.55560E -3  0.83330E -3  0.11110E -2  0.13890E -2  0.16670E -2  0.22220E -2

USER ID NUMBER =        200 NUMBER OF PLATFORMS =        10

BASE REPORTING RATES
0.69440E -4  0.13290E -3  0.27780E -3  0.55560E -3  0.83330E -3  0.13890E -2  0.16670E -2  0.19440E -2

USER ID NUMBER =        500 NUMBER OF PLATFORMS =         5

BASE REPORTING RATES
0.69440E -4  0.13890E -3  0.27780E -3  0.55560E -3  0.11110E -2  0.13890E -2  0.19440E -2  0.25000E -2

UNIT LOADING FACTOR =       5.00

MESSAGE REPITITION RATE =          3

MESSAGE DURATION =      2.00


         LOCAL DESIGN

         USER ID NUMBER =       100          NUMBER OF PLATFORMS =        15
```

Table A.5 (cont.)

```
HLAMJ           VARLJ
0.41433E -3          0.71931E -7


LOCAL DESIGN

USER ID NUMBER =        200          NUMBER OF PLATFORMS =        10

HLAMJ           VARLJ
0.45027E -3          0.14815E -6


LOCAL DESIGN

USER ID NUMBER =        500          NUMBER OF PLATFORMS =         5

HLAMJ           VARLJ
0.37944E -3          0.78638E -7



NATIONAL DESIGN

BLAMDA =  0.41468E -3 VARLB =  0.27970E -7

LOCAL DESIGN

USER ID NUMBER =        100          NUMBER OF PLATFORMS =        15
```

Table A.5 (cont.)

```
THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS  0.23148E -3

IT IS SATISFIED WITH PROBABILITY       0.2578

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS  0.27778E -2

IT IS SATISFIED WITH PROBABILITY       0.9999

 LOCAL DESIGN

 USER ID NUMBER =        200          NUMBER OF PLATFORMS =        10

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS  0.23148E -3

IT IS SATISFIED WITH PROBABILITY       0.2912

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS  0.41667E -2

IT IS SATISFIED WITH PROBABILITY       0.9999

 LOCAL DESIGN

 USER ID NUMBER =        500          NUMBER OF PLATFORMS =        5

THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS  0.23148E -3

IT IS SATISFIED WITH PROBABILITY       0.3085
```

Table A.5 (cont.)

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.83333E -2

IT IS SATISFIED WITH PROBABILITY 0.9999

NATIONAL DESIGN

THE MAXIMUM DETERMINISTIC REPORTING RATE AT 95% RELIABILITY OR MORE IS 0.13889E -2

IT IS SATISFIED WITH PROBABILITY 0.9999

A.5 Computer Equipment and Machine-Specific Issues

According to the contract, DCPMAIN was implemented in the NED Water Control Branch computer facilities. The machine used was a Data General NOVA3-12 with 64K words of memory and two disk drives. A large number of instructions appearing in the program are unfortunately machine-specific. They deal mostly with overlays definitions (required for execution in such a small machine) and in all input/output related statements, particularly file handling instructions.

The overlay structure is the following. The main program addresses the following groups of subroutines:

	Subroutine	Overlay
Group 1	INIT	1
Group 2	DATAIN	2
Group 3	SEARCH	3
	ALLOC	4
	LOCAL	5
Group 4	NATION	6
	RCOVAR	-

All overlay files are stored in a machine-readable file DCPMAIN.OL.

Following is a summary, by subroutine, of the main types of machine-specific statements.

DCPMAIN

- All CALL OVOPN
- All CALL OVLOD
- EXTERNAL one, two, three, four, five, six
- All CALL OPEN
- All CALL FOPEN
- All TYPE statements
- An "x" in column 1 signals the compiler to only load these statements if requested during compilation

INIT

- OVERLAY ONE
- Initialization of unit numbers or channels, which will be different for other machines

SEARCH

- OVERLAY THREE
- The random access file read begins in record zero. This may be a problem on other machines.
- CALL FSEEK
- TYPE STATEMENTS

DATAIN

- OVERLAY TWO
- TYPE STATEMENTS

ALLOC

- OVERLAY FOUR
- TYPE STATEMENTS
- CALL FSEEK

LOCAL

- OVERLAY FIVE
- Calls to FSEEK
- TYPE STATEMENTS

NATION

- OVERLAY SIX

RCOVAR

- Calls to FSEEK
- TYPE STATEMENTS

A.6 Changes to DCPMAIN

Future changes to DCPMAIN will probably deal with changing the number of precipitation stations affecting a user; changing the number of users; or changing the number of precipitation stations used in obtaining the probabilistic information. The following sub-sections summarize the main actions to take if the above changes are desired.

A.6.1 Changing the Number of Precipitation Stations Affecting a User

General Changes - All Subroutines/DCPMAIN

- Change all variables in COMMON currently dimensioned to 25 to whatever the maximum number of precipitation stations per user is desired.
- Change all DIMENSIONS STATEMENTS from 25 to whatever is desired.
- Change all DO LOOPS currently set for 25 repetitions to whatever is desired.

Subroutine-Specific Changes

SUBROUTINE SEARCH

Change statement:

IREC = IREC + 51 to

IREC = IREC + I

where I is the maximum total number of records per user in the User Information File, FIL1, including the user identification number.

SUBROUTINE ALLOC

Change statement:

IRECE = IRECS + 24 to

IRECE + IRECS + J

where J is the maximum number of precipitation stations per user minus 1.

A.6.2 Changing Number of Users

General Changes - All Subroutines/DCPMAIN

- Change all variables in COMMON currently dimensioned to 36 to whatever maximum number of users is desired.
- Change all DO LOOPS currently set for 36 repetitions to whatever maximum number of users is desired. These occur mostly in Subroutine INIT.

A.6.3 Changing Number of Precipitation Stations Used in Probabilistic Analysis

In order to change the number of precipitation stations in the analysis (i.e., stored in files FIL1, F2S1,2,3,4, F3S1,2,3,4) variable ICON1 in Subroutine INIT must be reset to exactly the number of stations analyzed by program ZAPPER.

A.7 The Mechanics of Using DCPMAIN in the NED Data General Computer

All subroutines are currently stored is separate files. Therefore, after editing an individual subroutine it must be recompiled by typing:

FORT subroutine file name

The subroutine file names are:

File	Subroutine
DCPMAIN	Main Program
DINIT	INIT
DATAIN	DATAIN
SEARCH	SEARCH
ALLOC	ALLOC
LOCAL	LOCAL
NATION	NATION
RCOVAR	RCOVAR

Due to the overlay structure, the entire program must be reloaded. This is done by typing:

DCPLOAD

or

RLDR DCPMAIN[DINIT,DATAIN,SEARCH ALLOC LOCAL,NATION RCOVAR]

To execute, type:

DCPMAIN

Output from DCPMAIN is stored on disk in file FIL5. To print results on your terminal, enter the following:

TYPE FIL5

When working on the Tektronix, printout may be routed to the Line Printer as follows:

PRINT FIL5

Make sure to position page before hitting return.

DCPMAIN

Program Listing

```
TYPE DCPMAIN
C      MAIN PROGRAM    DCP'S - LOCAL AND NATIONAL DESIGN -
C
C
       COMMON/IFILE/ICH0,ICH1,ICH2,ICH3,ICH4,ICH5
C
C
       COMMON/ALLC1/NPLAT(25,36),IPSID(25,36),IRECS(36)
C
C
       COMMON/DATA1/JID(36),NDCP(36),B(8,36)
C
C
       COMMON/CNTRL/JUSER,NUSER,ISEAS,ICON1,UNIT,DUR,IREP
C
C
       COMMON/STAT1/PRAINL(8,25,36),HLAMIJ(25,36),VLIJ(25,36),
     1              VARLJ(36),HLAMJ(36),VARLB,BLAMDA
C
         COMMON/DUMMY2/ XNORM(80)
C
       REAL MU1,MU2,MU3
       EXTERNAL ONE,TWO,THREE,FOUR,FIVE,SIX
C
C
         DATA XNORM/.0000,.0199,.0398,.0596,.0793,.0987,.1179,.1368
     1,.1554,.1736,.1915,.2088,.2257,.2422,.2580,.2734,.2881,.3023
     2,.3159,.3289,.3413,.3531,.3643,.3749,.3849,.3944,.4032,.4115
     3,.4192,.4265,.4332,.4394,.4452,.4505,.4554,.4599,.4641,.4678
     4,.4713,.4744,.4773,.4798,.4821,.4842,.4861,.4878,.4893,.4906
     5,.4918,.4929,.4938,.4946,.4953,.4960,.4965,.4970,.4974,.4978
     6,.4981,.4984,.49865,.4989,.49903,.4992,.49931,.49931,.49952,.49952
     7,.49966,.49966,.49977,.49977,.49984,.49984,.49989,.49989
     8,.49993,.49993,.49995,.49995/
C
C      INITIALIZE CONSTANTS AND VARIABLES
C
       ICH6=15
       CALL OVOPN(ICH6,'DCPMAIN.OL',IER)
       IF(IER.NE.1)TYPE 'OVOPN ERROR ',IER
       CALL OVLOD(ICH6,ONE,IER)
       CALL INIT
C
C      OPEN INPUT AND OUTPUT FILES
C
       CALL OPEN(ICH0,'FIL0',1,IER)
       IF(IER.NE.1) TYPE ' OPEN ERROR ',IER
       CALL OPEN(ICH5,'FIL5',3,IER)
       IF(IER.NE.1) TYPE ' OPEN ERROR ',IER
C
C      READ INPUT DATA DECK
C
       CALL OVLOD(ICH6,TWO,IER)
       CALL DATAIN
C
C      OPEN DATA FILES FOR SEASON, ISEAS
       TYPE 'START'
C
```

```
      GO TO (10,20,30,40),ISEAS
C
   10 CALL FOPEN(ICH1,'FIL1',31)
      CALL FOPEN(ICH2,'F2S1',103)
      CALL FOPEN(ICH3,'F3S1',73)
      GO TO 50
C
C
   20 CALL FOPEN(ICH1,'FIL1',31)
      CALL FOPEN(ICH2,'F2S2',103)
      CALL FOPEN(ICH3,'F3S2',73)
      GO TO 50
C
C
   30 CALL FOPEN(ICH1,'FIL1',31)
      CALL FOPEN(ICH2,'F2S3',103)
      CALL FOPEN(ICH3,'F3S3',73)
      GO TO 50
C
C
   40 CALL FOPEN(ICH1,'FIL1',31)
      CALL FOPEN(ICH2,'F2S4',103)
      CALL FOPEN(ICH3,'F3S4',73)
C
   50 CONTINUE
C
C
      TYPE 'EXECUTION'
C     BEGIN PROCESSING FOR LOCAL DESIGN
C
      DO 100 JUSER=1,NUSER
      CALL OVLOD(ICH6,THREE,IER)
      CALL SEARCH(ICH1,JID(JUSER),IRECS(JUSER))
      CALL OVLOD(ICH6,FOUR,IER)
      CALL ALLOC(ICH1,IRECS(JUSER),NDCP(JUSER),NPLAT(1,JUSER),
     1           IFSID(1,JUSER))
X      TYPE 'NPLAT',NPLAT(1,JUSER)
      CALL OVLOD(ICH6,FIVE,IER)
      CALL LOCAL
  100 CONTINUE
C
C     BEGIN PROCESSING FOR NATIONAL DESIGN
C
      CALL OVLOD(ICH6,SIX,IER)
      CALL NATION
C
C
C
      DO 200 JUSER=1,NUSER
      WRITE(ICH5,6000)
      WRITE(ICH5,6010)JID(JUSER),NDCP(JUSER)
      WRITE(ICH5,6020)
      WRITE(ICH5,6030)HLAMJ(JUSER),VARLJ(JUSER)
  200 CONTINUE
      WRITE(ICH5,6040)
      WRITE(ICH5,6050)BLAMDA,VARLB
C
```

```
C
C
      ITOTST=0
      TOTST=0.0
      XLAMP=UNIT/(3600.*DUR*IREP)
C
C
      DO 300 JUSER=1,NUSER
      XLAMPP=1.0/(4*NDCP(JUSER)*DUR*IREP)
      STD=SQRT(VARLJ(JUSER))
      MU1=(XLAMPP-HLAMJ(JUSER))/STD
      IF(MU1.LT.0) IFLAG=1
      IF(MU1.GE.0) IFLAG=0
      MU1=ABS(MU1)
      MU2=(XLAMP-HLAMJ(JUSER))/STD
      IF(MU2.LT.0) IFLAG2=1
      IF(MU2.GE.0) IFLAG2=0
      MU2=ABS(MU2)
      ITOTST=ITOTST+NDCP(JUSER)
C
C
      DO 310 K=1,80
      L=K-1
      XN=(K-1)*0.05
      IF(MU1.LT.XN) GO TO 315
  310 CONTINUE
X      TYPE 'K',K
X      TYPE 'MU1',MU1
X      TYPE 'MU2',MU2
X      TYPE 'XNORM(L)',XNORM(L)
  315 P0=XNORM(L)+0.5
      IF(IFLAG.EQ.1)P0=1.0-P0
C
C
      DO 320 K=1,80
      L=K-1
      XN=(K-1)*0.05
      IF(MU2.LT.XN) GO TO 325
  320 CONTINUE
C
  325 P1=XNORM(L)+0.5
      IF(IFLAG2.EQ.1)P1=1.0-P1
C
C
      WPITE(ICH5,6000)
      WRITE(ICH5,6010) JID(JUSER),NDCP(JUSER)
      WRITE(ICH5,6060) XLAMP
      WRITE(ICH5,6070) P1
      WRITE(ICH5,6080)XLAMPP
      WRITE(ICH5,6090) P0
C
C
  300 CONTINUE
C
C
      XLAMS=1.0/(4*ITOTST*DUR*IREP)
      MU3=(XLAMS-BLAMDA)/SQRT(VARLB)
      IF(MU3.LT.0)IFLAG3=1
```

```
      IF(MU3.GE.0) IFLAG3=0
      MU3=ABS(MU3)
C
      DO 340 K=1,80
      L=K-1
      XN=(K-1)*0.05
      IF(MU3.LT.XN) GO TO 345
  340 CONTINUE
C
  345 P2=XNORM(L)+0.5
      IF(IFLAG3.EQ.1)P2=1.0-P2
C
C
      WRITE(ICH5,6040)
      WRITE(ICH5,6080) XLAMS
      WRITE(ICH5,6090) P2
C
C
C
 6000 FORMAT(////,10X,' LOCAL DESIGN ')
 6010 FORMAT(///,10X,' USER ID NUMBER = ',I10,
     1          10X,' NUMBER OF PLATFORMS = ',I10)
 6020 FORMAT(///,10X,' HLAMJ ',10X,' VARLJ ')
 6030 FORMAT(/,10X,E12.5,10X,E12.5)
 6040 FORMAT(//////,10X,' NATIONAL DESIGN ')
 6050 FORMAT(///,10X,' BLAMDA = ',E12.5,' VARLB = ',E12.5)
 6060 FORMAT(///,10X,'THE MAXIMUM REPORTING RATE BASED ON UNIT LOAD IS ',E12.5)
 6070 FORMAT(///,10X,'IT IS SATISFIED WITH PROBABILITY ',F12.4)
 6080 FORMAT(///,10X,'THE MAXIMUM DETERMINISTIC REPORTING RATE
     1 AT 95% RELIABILITY OR MORE IS ',E12.5)
 6090 FORMAT(///,10X,'IT IS SATISFIED WITH PROBABILITY ',F12.4)
C
C
      STOP
      END
/*
R
```

```
TYPE DINIT
      OVERLAY ONE
      SUBROUTINE INIT
C
C
      COMMON/IFILE/ICH0,ICH1,ICH2,ICH3,ICH4,ICH5
C
C
      COMMON/ALLC1/NPLAT(25,36),IPSID(25,36),IRECS(36)
C
C
      COMMON/DATA1/JID(36),NDCP(36),B(8,36)
C
C
      COMMON/CNTRL/JUSER,NUSER,ISEAS,ICON1,UNIT,DUR,IREP
C
C
      COMMON/STAT1/PRAINL(8,25,36),HLAMIJ(25,36),VLIJ(25,36),
     1          VARLJ(36),HLAMJ(36),VARLB,BLAMDA
C
C
C
C     INITIALIZES CONSTANTS AND VARIABLES
C
C
      DO 200 I=1,25
      DO 200 J=1,36
      NPLAT(I,J)=0
      IPSID(I,J)=0
      HLAMIJ(I,J)=0.
      VLIJ(I,J)=0.
  200 CONTINUE
C
C
      DO 300 I=1,36
      IRECS(I)=0
      JID(I)=0
      NDCP(I)=0
      VARLJ(I)=0.
      HLAMJ(I)=0.
  300 CONTINUE
C
C
      DO 400 I=1,8
      DO 400 J=1,25
      DO 400 K=1,36
      PRAINL(I,J,K)=0.
  400 CONTINUE
C
C
      DO 600 I=1,8
      DO 600 J=1,36
      B(I,J)=0.
  600 CONTINUE
C
      JUSER=0
      NUSER=0
      ISEAS=0
      ICON1= 255
      VARLB=0.
      BLAMDA=0.
      ICH0=3
      ICH1=4
      ICH2=7
      ICH3=8
      ICH5=13
C
C
      RETURN
      END
R
```

```
TYPE DATAIN
      OVERLAY TWO
      SUBROUTINE DATAIN
C
C
      COMMON/IFILE/ICH0,ICH1,ICH2,ICH3,ICH4,ICH5
C
C
      COMMON/ALLC1/NPLAT(25,36),IPSID(25,36),IRECS(36)
C
C
      COMMON/DATA1/JID(36),NDCP(36),B(8,36)
C
C
      COMMON/CNTRL/JUSER,NUSER,ISEAS,ICON1,UNIT,DUR,IREP
C
C
      COMMON/STAT1/PRAINL(8,25,36),HLAMIJ(25,36),ULIJ(25,36),
     1             VARLJ(36),HLAMJ(36),VARLB,BLANDA
C
C
C     READ INPUT DATA DECK
C
C     READ NO. OF USERS (NUSER)
C
      READ(ICH0,5010) NUSER
C
C     LOOP OVER USER INPUT CARDS
C
      DO 100 J=1,NUSER
      READ(ICH0,5020) JID(J),NDCP(J)
      READ(ICH0,5030) (B(IRATE,J),IRATE=1,8)
  100 CONTINUE
C
C     READ SEASON ID CARD
C
      READ(ICH0,5010) ISEAS
C
C
C     READ CHANNEL LOADING UNIT LOAD VALUE
C
C
      READ(ICH0,5040) UNIT
C
C     READ NO. OF REPITITIONS TO BE MADE
C
      READ(ICH0,5010) IREP
C
C     READ MESSAGE DURATION
C
      READ(ICH0,5040) DUR
C
C     ECHO PRINT USER INPUT
C
      WRITE(ICH5,6010)
      WRITE(ICH5,6020) NUSER
C
      DO 300 I=1,NUSER
      WRITE(ICH5,6030) JID(I),NDCP(I)
X      TYPE 'B',(B(IRATE,I),IRATE=1,8)
      WRITE(ICH5,6040) (B(IRATE,I),IRATE=1,8)
  300 CONTINUE
C
      WRITE(ICH5,6050) UNIT
      WRITE(ICH5,6060) IREP
      WRITE(ICH5,6070) DUR
C
C
C
 5010 FORMAT(I10)
 5020 FORMAT(2I10)
 5030 FORMAT(8(1X,E9.7))
 5040 FORMAT(F10.3)
C
 6010 FORMAT(///,1X,' ECHO PRINT OF USER INPUT DECK ')
 6020 FORMAT(///,1X,' TOTAL NUMBER OF USERS (NUSER) = ',I10)
 6030 FORMAT(//,1X,' USER ID NUMBER = ',I10,
     1      ' NUMBER OF PLATFORMS = ',I10)
 6040 FORMAT(//,1X,' BASE REPORTING RATES ',//,8(1X,E12.5))
 6050 FORMAT(///,1X,' UNIT LOADING FACTOR = ',F10.2)
 6060 FORMAT(///,1X,' MESSAGE REPITITION RATE = ',I10)
 6070 FORMAT(///,1X,' MESSAGE DURATION = ',F10.2,///)
C
C
      RETURN
      END
R
```

```
TYPE SEARCH
      OVERLAY THREE
      SUBROUTINE SEARCH (ICH1,JID,IRECS)
C
C
C     FINDS STARTING LOCATION FOR DATA IN USER INFORMATION FILE
C
C
      IREC=0
C
  100 CONTINUE
      CALL FSEEK (ICH1,IREC)
      READ(ICH1,5000,END=1000,ERR=2000) IDNO
      IF(JID.EQ.IDNO) GO TO 200
      TYPE 'JID = ',JID
      TYPE 'IDNO = ',INDO
      IREC=IREC+51
      GO TO 100
C
C
C
  200 CONTINUE
      IRECS=IREC+1
      RETURN
C
C
 1000 TYPE ' END OF FILE ENCOUNTERED DURING READ AT LOCATION ',IREC
      TYPE ' FROM SEARCH ON DEVICE ',ICH1
      STOP
C
 2000 TYPE ' ERROR IN SEARCH AT RECORD ',IREC
      TYPE ' FROM SEARCH ON DEVICE ',ICH1
      STOP
C
C
 5000 FORMAT(I10)
      END
R
```

```
TYPE ALLOC
      OVERLAY FOUR
      SUBROUTINE ALLOC (ICH1,IRECS,NDCP,NPLAT,IPSID)
C
C     ALLOCATES NO. OF DCPS IN USER J TO THISSEN AREAS
C     ASSUMES DCPS ARE UNIFORMLY DISTRIBUTED WITHIN A GIVEN USER
C
      DIMENSION NPLAT(25),IPSID(25)
X      TYPE 'ICH1 = ',ICH1
X      TYPE 'NDCP = ',NDCP
X      TYPE 'IRECS = ',IRECS
      TAREA=0.
      TMAX=0.
      ICOUNT=0
      IRECE=IRECS+24
C
X      TYPE 'IRECS = ',IRECS
C
      DO 100 JREC=IRECS,IRECE
      ICOUNT=ICOUNT+1
      CALL FSEEK (ICH1,JREC)
      READ(ICH1,5000,END=2000,ERR=3000) IPSID(ICOUNT),PAREA
X      TYPE 'IPSID(ICOUNT) = ',IPSID(ICOUNT)
X      TYPE 'PAREA = ',PAREA
C
      IF(PAREA.GT.TMAX) TMAX=PAREA
      IF(PAREA.EQ.TMAX) JMAX=ICOUNT
C
      TAREA=TAREA+PAREA
      NPLAT(ICOUNT)=NDCP*PAREA+0.5
  100 CONTINUE
C
      IF(TAREA.GT.1.005) GO TO 4000
      IF(TAREA.LT.0.995) GO TO 4000
C
      LPLAT=0
C
      DO 200 L=1,25
      LPLAT=LPLAT+NPLAT(L)
  200 CONTINUE
C
C
  250 CONTINUE
      IF(LPLAT.GT.NDCP) GO TO 300
      IF(LPLAT.LT.NDCP) GO TO 400
      RETURN
C
C
  300 CONTINUE
      NPLAT(JMAX)=NPLAT(JMAX)-1
      LPLAT=LPLAT-1
      GO TO 250
C
C
  400 CONTINUE
      NPLAT(JMAX)=NPLAT(JMAX)+1
```

```
      LPLAT=LPLAT+1
      GC TO 250
C
C
 2000 TYPE' END OF FILE ENCOUNTERED DURING READ AT LOCATION ',JREC
      TYPE ' FROM ALLOC ON DEVICE ',ICH1
      STOP
C
C
 3000 TYPE ' ERROR IN ALLOC AT RECORD ',JREC
      STOP
C
 4000 TYPE' TOTAL AREA NE 100%....ERROR IN UIF '
      STOP
C
 5000 FORMAT(I10,10X,F10.3)
C
      END

P
```

```
TYPE LOCAL
      OVERLAY FIVE
      SUBROUTINE LOCAL
C
C
C
      COMMON/IFILE/ICH0,ICH1,ICH2,ICH3,ICH4,ICH5
C
C
      COMMON/ALLC1/NPLAT(25,36),IPSID(25,36),IRECS(36)
C
C
      COMMON/DATA1/JID(36),NDCP(36),B(8,36)
C
C
      COMMON/CNTRL/JUSER,NUSER,ISEAS,ICON1,UNIT,DUR,IREP
C
C
      COMMON/STAT1/PRAINL(8,25,36),HLAMIJ(25,36),VLIJ(25,36),
     1          VARLJ(36),HLAMJ(36),VARLB,BLAMDA
C
C
C
C     LOAD RAINFALL INTERVAL PROBABILITIES FOR USER J , SEASON ISEAS
C
C
      DIMENSION PCOND(4),COV(25,25)
C
      DO 300 IGAGE=1,25
      IF(IPSID(IGAGE,JUSER).EQ.0) GO TO 300
      IREC=IPSID(IGAGE,JUSER)
C
        ITREC=IREC-1   ;TO AVOID BLANK 0 RECORDS
      CALL FSEEK (ICH2,ITREC)
      READ(ICH2,5000) LSTA,LSEAS,(PRAINL(IRATE,IGAGE,JUSER),IRATE=1,8)
X      TYPE 'IPSID(IGAGE,JUSER) = ',IPSID(IGAGE,JUSER)
X      TYPE 'LSTA= ',LSTA
      IF(IPSID(IGAGE,JUSER).NE.LSTA) GO TO 7000
      IF(ISEAS.NE.LSEAS) GO TO 7010
C
      HLAMIJ(IGAGE,JUSER)=B(1,JUSER)*PRAINL(1,IGAGE,JUSER)
C
      DO 200 IRATE=2,8
      HLAMIJ(IGAGE,JUSER)=HLAMIJ(IGAGE,JUSER)
     1          +B(IRATE,JUSER)*PRAINL(IRATE,IGAGE,JUSER)
     2          *(1.0-PRAINL(1,IGAGE,JUSER))
  200 CONTINUE
C
  300 CONTINUE
C
C     COMPLTE COVARIANCE (I1,I2)
X      TYPE 'IPSID ',(IPSID(IGAGE,JUSER),IGAGE=1,25)
C     INITIALIZE COVARIANCE MATRIX FOR LOCAL DESIGN
C
      DO 400 I=1,25
      DO 400 J=1,25
      COV(I,J)=0.0
  400 CONTINUE
```

```
C
C
      DO 1000 IGAGE=1,25
      IF(IPSID(IGAGE,JUSER).EQ.0) GO TO 1000
C
C
      DO 900 JGAGE=1,25
C
      IF(IPSID(JGAGE,JUSER).EQ.IPSID(IGAGE,JUSER)) GO TO 900
      IF(IPSID(JGAGE,JUSER).EQ.0) GO TO 900
C
C
C
      ITEMP1=IPSID(IGAGE,JUSER)
      ITEMP2=IPSID(JGAGE,JUSER)
C
      IF(ITEMP1.GT.ITEMP2) GO TO 410
      IFLAG=0
      GO TO 420
C
  410 ITEMP2=IPSID(IGAGE,JUSER)
      ITEMP1=IPSID(JGAGE,JUSER)
      IFLAG=1
C
  420 LREC=0
      DO 430 ISTA1=1,ICON1
      LREC=LREC+(ICON1-ISTA1)
      IF(ISTA1.EQ.ITEMP1) GO TO 440
  430 CONTINUE
C
  440 LREC=LREC-(ICON1-ITEMP2)
C
X       TYPE 'LREC=',LREC
X       TYPE 'IFLAG=',IFLAG
X       TYPE 'ITEMP1=',ITEMP1
X       TYPE 'ITEMP2=',ITEMP2
X       TYPE 'IPSID(IGAGE,JUSER)',IPSID(IGAGE,JUSER)
X       TYPE 'IPSID(JGAGE,JUSER)',IPSID(JGAGE,JUSER)
        LTREC=LREC-1
      CALL FSEEK (ICH3,LTREC)
      READ(ICH3,5010) ICK1,ICK2,ICK3,(PCOND(N),N=1,4)
C
X       TYPE 'IPSID # = ',IPSID(IGAGE,JUSER)
X       TYPE 'ICK1 = ',ICK1
      IF(ICK1.NE.ITEMP1)GO TO 7020
      IF(ICK2.NE.ITEMP2)GO TO 7030
      IF(ICK3.NE.ISEAS) GO TO 7040
C
C
      IF(IFLAG.EQ.1)GO TO 450
      GO TO 460
C
  450 TEMP1=PCOND(2)
      PCOND(2)=PCOND(3)
      PCOND(3)=TEMP1
C
  460 CONTINUE
C
```

```
C
      CTERM1=(B(1,JUSER)-HLAMIJ(IGAGE,JUSER))
     1          *(B(1,JUSER)-HLAMIJ(JGAGE,JUSER))
     2          *PCOND(1)
C
      CTERM2=0.
      DO 500 L=2,8
      CTERM2=CTERM2+B(L,JUSER)*PRAINL(L,JGAGE,JUSER)
  500 CONTINUE
      CTERM2=(CTERM2-HLAMIJ(JGAGE,JUSER))
     1        *(B(1,JUSER)-HLAMIJ(IGAGE,JUSER))
     2        *PCOND(2)
C
      CTERM3=0
      DO 600 L=2,8
      CTERM3=CTERM3+(B(L,JUSER)*PRAINL(L,IGAGE,JUSER))
  600 CONTINUE
      CTERM3=(CTERM3-HLAMIJ(IGAGE,JUSER))
     1        *(B(1,JUSER)-HLAMIJ(JGAGE,JUSER))
     2        *PCOND(3)
C
      CT4A=0.0
      DO 700 L1=2,8
      CT4A=CT4A+B(L1,JUSER)*PRAINL(L1,IGAGE,JUSER)
  700 CONTINUE
      CT4A=CT4A-HLAMIJ(IGAGE,JUSER)
      CT4B=0.0
      DO 750 L2=2,8
      CT4B=CT4B+B(L2,JUSER)*PRAINL(L2,JGAGE,JUSER)
  750 CONTINUE
      CT4B=CT4B-HLAMIJ(JGAGE,JUSER)
      CTERM4=CT4A*CT4B*PCOND(4)
X       TYPE 'CTERM1',CTERM1
X       TYPE 'CTERM2',CTERM2
X       TYPE 'CTERM3',CTERM3
X       TYPE 'CTERM4',CTERM4
C
C
      COV(IGAGE,JGAGE)=CTERM1+CTERM2+CTERM3+CTERM4
C
C
X       TYPE 'COV(IGAGE,JGAGE)',COV(IGAGE,JGAGE)
  900 CONTINUE
C
 1000 CONTINUE
C
C
C     COMPUTE THE VARIANCE OF LAMDA I,J
C
C
      DO 1200 IGAGE=1,25
C
      IF(IPSID(IGAGE,JUSER).EQ.0) GO TO 1200
C
      VLIJ1=(B(1,JUSER)-HLAMIJ(IGAGE,JUSER))**2
     1          *PRAINL(1,IGAGE,JUSER)
C
      VLIJ2=0
```

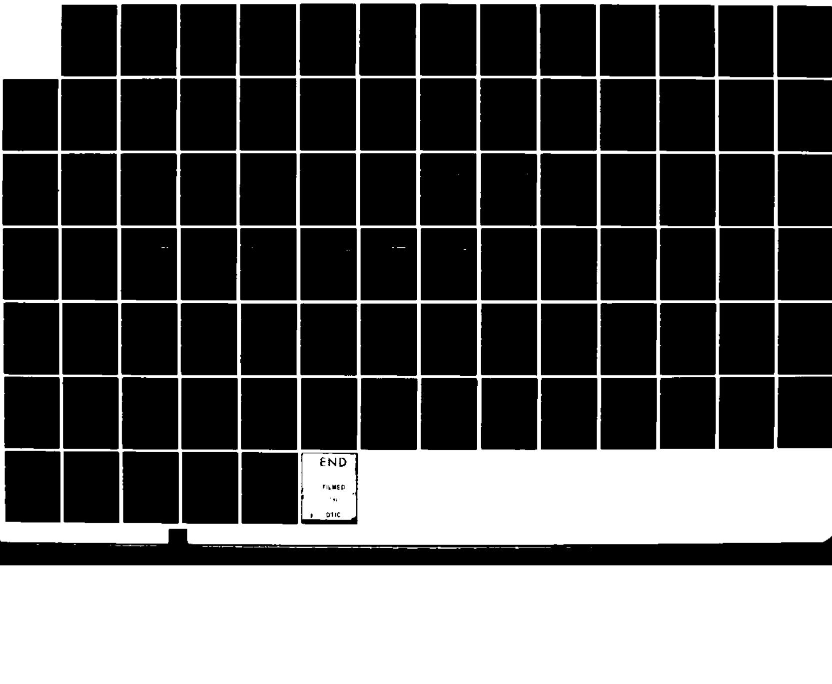
```
      DO 1100 L=2,8
      VLIJ2=VLIJ2+(B(L,JUSER)-HLAMIJ(IGAGE,JUSER))**2
     1          *PRAINL(L,IGAGE,JUSER)*(1.0-PRAINL(1,IGAGE,JUSER))
 1100 CONTINUE
C
C
      VLIJ(IGAGE,JUSER)=VLIJ1+VLIJ2
C
C
X      TYPE 'VLIJ(IGAGE,JUSER)=',VLIJ(IGAGE,JUSER)
 1200 CONTINUE
C
C
C     COMPUTE THE VARIANCE OF LAMDA J
C
C
      SVAR=0
C
      DO 1500 IGAGE=1,25
C
      IF(IPSID(IGAGE,JUSER).EQ.0) GO TO 1500
C
      SCOV=0
C
      DO 1400 JGAGE=1,25
C
      IF(IPSID(IGAGE,JUSER).EQ.IPSID(JGAGE,JUSER)) GO TO 1400
      IF(IPSID(JGAGE,JUSER).EQ.0) GO TO 1400
C
      SCOV=SCOV+COV(IGAGE,JGAGE)
     1          *NPLAT(IGAGE,JUSER)*NPLAT(JGAGE,JUSER)*2
X      TYPE 'SCOV=',SCOV
X      TYPE 'NPLAT(IGAGE)',NPLAT(IGAGE,JUSER)
X      TYPE 'NPLAT(JGAGE)',NPLAT(JGAGE,JUSER)
 1400 CONTINUE
C
Fact = NPLAT(IGAGE JUSER)**2 - NPLAT(IGAGE, JUSER)


C
      SVAR=SVAR+VLIJ(IGAGE,JUSER)*
     1          (NPLAT(IGAGE,JUSER)+FACT)+SCOV
C
X      TYPE 'SVAR',SVAR
 1500 CONTINUE
X      TYPE 'NDCP(JUSER)',NDCP(JUSER)
C
      ZNDCP=NDCP(JUSER)
      VARLJ(JUSER)=(1/ZNDCP)**2*SVAR
C
X      TYPE 'JUSER',JUSER
X      TYPE 'VARLJ(JUSER)',VARLJ(JUSER)
C     COMPUTE THE MEAN OF LAMDA HAT J
C
```

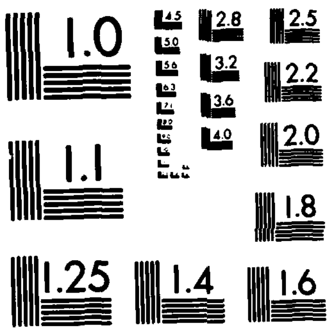
```
C
      SMEAN=0
C
      DO 1600 IGAGE=1,25
C
      IF(IPSID(IGAGE,JUSER).EQ.0) GO TO 1600
C
      SMEAN=SMEAN+HLAMIJ(IGAGE,JUSER)*NPLAT(IGAGE,JUSER)
 1600 CONTINUE
C
      HLAMJ(JUSER)=(1/ZNDCP)*SMEAN
C
C
X      TYPE 'HLAMJ(JUSER)',HLAMJ(JUSER)
C
C
C
      RETURN
C
C
C
C
 5000 FORMAT(2I10,8F10.3)
 5010 FORMAT(3I10,4F10.3)
C
C
C
 7000 TYPE ' ERROR IN SUB LOCAL $7000 AT RECORD ',IREC
      STOP
 7010 TYPE ' ERROR IN SUB LOCAL $7010 AT RECORD ',IREC
      STOP
 7020 TYPE ' ERROR IN SUB LOCAL $7020 AT RECORD ',LREC
      STOP
 7030 TYPE ' ERROR IN SUB LOCAL $7030 AT RECORD ',NREC
      STOP
 7040 TYPE ' ERROR IN SUB LOCAL $7040 AT RECORD ',NREC
      STOP
C
C
      END
R
```

```
TYPE NATION
      OVERLAY SIX
      SUBROUTINE NATION
C
C
C
C
C
C
      COMMON/IFILE/ICH0,ICH1,ICH2,ICH3,ICH4,ICH5
C
C
      COMMON/ALLC1/NPLAT(25,36),IPSID(25,36),IRECS(36)
C
C
      COMMON/DATA1/JID(36),NDCP(36),B(8,36)
C
C
      COMMON/CNTRL/JUSER,NUSER,ISEAS,ICON1
C
C
      COMMON/STAT1/PRAINL(8,25,36),HLAMIJ(25,36),VLIJ(25,36),
     1          VARLJ(36),HLAMJ(36),VARLB,BLAMDA
C
C
C     COMPUTE THE VARIANCE OF LAMDA BAR
C
C
C
C
C
      VARLB1=0.
C
      DO 800 JUSER1=1,NUSER
C
      DO 700 ISTA=1,ICON1
C
      DO 100 IGAGE=1,25
C
      IF(ISTA.EQ.IPSID(IGAGE,JUSER1)) GO TO 200
      IF(IPSID(IGAGE,JUSER1).EQ.0) GO TO 700
  100 CONTINUE
C
C
  200 CONTINUE
C
C
      DO 600 JUSER2=1,NUSER
C
      IF(JUSER1.EQ.JUSER2) GO TO 600
C
      DO 500 JSTA=1,ICON1
C
      DO 300 JGAGE=1,25
C
      IF(JSTA.EQ.IPSID(JGAGE,JUSER2)) GO TO 400
      IF(IPSID(JGAGE,JUSER2).EQ.0) GO TO 500
  300 CONTINUE
C
C
  400 CONTINUE
C
C
C     COMPUTE COVARIANCE TERMS
C
      CALL RCOVAR(JUSER1,JUSER2,IGAGE,JGAGE,COVJ)
C
C
      XNDCP=NDCP(JUSER1)
      YNDCP=NDCP(JUSER2)
      VARLB1=VARLB1+(1/(XNDCP*YNDCP))
     1          *COVJ*NPLAT(IGAGE,JUSER1)*NPLAT(JGAGE,JUSER2)
*2
  500 CONTINUE
C
  600 CONTINUE
C
  700 CONTINUE
C
  800 CONTINUE
C
C
      VARLB2=0.
C
      DO 900 JUSER=1,NUSER
      VARLB2=VARLB2+VARLJ(JUSER)
  900 CONTINUE
C
C
      ZNUSER=NUSER
      VARLB=(1/ZNUSER**2)*VARLB2+(1/(ZNUSER)**2)*VARLB1
C
C
      BLAMDA=0.
C
      DO 1000 JUSER=1,NUSER
      BLAMDA=BLAMDA+(1/ZNUSER)*HLAMJ(JUSER)
 1000 CONTINUE
C
C
C
C
      RETURN
      END
R
```

AD-A122 629 A METHODOLOGY FOR ANALYZING THE EFFECT OF HYDROMETEOROLOGY OF THE CONTIGU..(U) BRAS (RAFAEL L) LEXINGTON MA R L BRAS ET AL. AUG 82 DACW33-82-C-0011 3/3

UNCLASSIFIED F/G 4/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
TYPE RCOVAR
      SUBROUTINE RCOVAR(JUSER1,JUSER2,IGAGE,JGAGE,COVJ)
C
C
      COMMON/IFILE/ICH0,ICH1,ICH2,ICH3,ICH4,ICH5
C
C
      COMMON/ALLC1/NPLAT(25,36),IPSID(25,36),IRECS(36)
C
C
      COMMON/DATA1/JID(36),NDCP(36),B(8,36)
C
C
      COMMON/CNTRL/JUSER,NUSER,ISEAS,ICON1
C
C
      COMMON/STAT1/PRAINL(8,25,36),HLAMIJ(25,36),VLIJ(25,36),
     1          VARLJ(36),HLAMJ(36),VARLB,BLAMDA
C
C
      DIMENSION PCOND(4)
C
C
      IF(JUSER1.EQ.JUSER2) GO TO 900
C
C     LOOK UP CONDITIONAL PROBABILITIES
C
      IF(IPSID(IGAGE,JUSER1).EQ.IPSID(JGAGE,JUSER2))GO TO 460
C
      ITEMP1=IPSID(IGAGE,JUSER1)
      ITEMP2=IPSID(JGAGE,JUSER2)
C
      IF(ITEMP1.GT.ITEMP2) GO TO 410
      IFLAG=0
      GO TO 420
C
  410 ITEMP2=IPSID(IGAGE,JUSER1)
      ITEMP1=IPSID(JGAGE,JUSER2)
      IFLAG=1
C
  420 LREC=3
      DO 430 ISTA1=1,ICON1
      LREC=LREC+(ICON1-ISTA1)
      IF(ISTA1.EQ.ITEMP1) GO TO 440
  430 CONTINUE
C
  440 LREC=LREC-(ICON1-ITEMP2)
C
        LTREC=LREC-1
      CALL FSEEK (ICH3,LTREC)
      TYPE 'LREC',LREC
      TYPE 'ICK1',ICK1
      TYPE 'ITEMP1',ITEMP1
      TYPE 'ITEMP2',ITEMP2
      TYPE 'IPSID(IGAGE,JUSER1)',IPSID(IGAGE,JUSER1)
      TYPE 'IPSID(JGAGE,JUSER2)',IPSID(JGAGE,JUSER2)
      TYPE 'JUSER1',JUSER1
      TYPE 'JUSER2',JUSER2
```

```
      READ(ICH3,5010) ICK1,ICK2,ICK3,(PCOND(N),N=1,4)
      IF(ICK1.NE.ITEMP1) GO TO 7010
      IF(ICK2.NE.ITEMP3) GO TO 7020
      IF(ICK3.NE.ISEAS) GO TO 7030
C
C
      IF(IFLAG.EQ.1) GO TO 450
      GO TO 480
C
  450 TEMP1=PCOND(2)
      PCOND(2)=PCOND(3)
      PCOND(3)=TEMP1
      GO TO 480
C
  460 CONTINUE
      PCOND(1)=PRAINL(1,IGAGE,JUSER1)
      PCOND(2)=0
      PCOND(3)=0
      PCOND(4)=1.0-PRAINL(1,IGACE,JUSER1)
C
C
  480 CONTINUE
C
      CTERM1=(B(1,JUSER1)-HLAMIJ(IGAGE,JUSER1))
     1          *(B(1,JUSER2)-HLAMIJ(JGAGE,JUSER2))
     2          *PCOND(1)
C
      CTERM2=0.
      DO 500 L=2,8
      CTERM2=CTERM2+B(L,JUSER2)*PRAINL(L,JGAGE,JUSER2)
  500 CONTINUE
      CTERM2=(CTERM2-HLAMIJ(JGAGE,JUSER2))
     1        *(B(1,JUSER1)-HLAMIJ(IGAGE,JUSER1))
     2        *PCOND(2)
C
      CTERM3=0.0
      DO 600 L=2,8
      CTERM3=CTERM3+(B(L,JUSER1)*PRAINL(L,IGAGE,JUSER1))
  600 CONTINUE
      CTERM3=(CTERM3-HLAMIJ(IGACE,JUSER1))
     1        *(B(1,JUSER2)-HLAMIJ(JGAGE,JUSER2))
     2        *PCOND(3)
C
      CT4A=0.0
      DC 700 L1=2,8
      CT4A=CT4A+B(L1,JUSER1)*PRAINL(L1,IGAGE,JUSER1)
  700 CONTINUE
      CT4B=0.0
      DO 750 L2=2,8
      CT4B=CT4B+B(L2,JUSER2)*PRAINL(L2,JGAGE,JUSER2)
  750 CONTINUE
      CT4B=CT4B-HLAMIJ(JGAGE,JUSER2)
      CT4A=CT4A-HLAMIJ(IGAGE,JUSER1)
      CTERM4=CT4A*CT4B*PCOND(4)
C
C
C
      COVJ=CTERM1+CTERM2+CTERM3+CTERM4
```

```
      TYPE '              COVJ',COVJ
C
C
  900 CONTINUE
C
 5010 FORMAT(3I10,4F10.3)
      RETURN
C
C
 7010 TYPE ' ERROR IN SUB RCOVAR $7010 AT RECORD ',LREC
      STOP
 7020 TYPE ' ERROR IN SUB RCOVAR $7020 AT RECORD ',NREC
      STOP
 7030 TYPE ' ERROR IN SUB RCOVAR $7030 AT RECORD ',NREC
      STOP
C
C
      END
/$

R
```

APPENDIX B

Preprocessing Program

Documentation

B.1 Introduction

This Appendix contains program listings and information on use of a series of programs designed to provide the necessary input data file, for application of DCPMAIN, as described in Appendix A. Four separate programs were developed as follows:

1. CAPPER - designed to take as input the Corps of Engineers district boundaries and generate a digitized map of the conterminous United States C of E districts;
2. MAPPER - using output map and raingage station location data, evaluates Thiessen areas of influence for all gauging stations and all districts of interest producing FIL1, the user information file;
3. ZAPPER - developed to process the National Weather Service Techniques Development Laboratory data set of 6-hour rainfall amounts for 255 gauging stations, and generate statistics on numbers on rainfall events by depth interval and number of events of joint occurrence of rainfall between pairs of stations;

4. TAPPER - takes number of events files generated and converts to probabilities of occurrence, the so-called files F2S1, F2S2, F2S3, F2S4, F3S1, F3S2, F3S3, and F3S4 files required for use by DCPMAIN.

These preprocessing programs are documented in the sections that follow, but the purpose is not to provide a comprehensive users manual. The programs were designed to analyze and generate all of the key statistics required by DCPMAIN regardless of the manner in which the C of E districts were to be assigned to channels for random reporting. The data needed for considering of the existing 36 C of E district users for the conterminous United States were generated in the course of executing these preprocessing modules. Thus, these programs were designed to be executed only once -- and need not concern the user of DCPMAIN, only the output files from these models which have been supplied with DCPMAIN, are required. However, should a change be required in the basic input used in preprocessing, namely, the existing 36 Corps districts and the use of the 255 station NWSTDC Data set, then the preprocessing modules would have to be rerun.

6.2 Program CAPPER

Program CAPPER written in standard Fortran IV was implemented and executed on the NED Data General NOVA 3-12 discussed in Section A.5. The program listing is included at the end of this section, followed by file BOUNDARY, the input file for CAPPER.

As currently configured, the program is designed to construct a digitized map for which each grid point is associated to a separate district. The key controlling parameters initialized in the program are:

NLAT - the number of grid points into which the y-axis of the map is discretized (rows);

NLON - the number of grid points into which the x-axis is discretized (columns);

NDIS - the maximum number of distinct districts.

As executed, the map grid was intended to represent the continental United States C of E districts, totaling NDIS = 36. The base map used to develop the digitized representation was the December 1970 Division and District Boundaries for Civil Works Activities, where the map grid was divided into NLAT = 136 by NLON = 224 points. At this level of discretization each grid point was roughly 204 square miles.

The reason the digitized map was not input directly was that the amount of input information required, namely the district number associated to each of the 30464 points in the grid, was too massive.

Instead it was recognized that all that was required to construct the map was data on the points at which district numbers changed, and the nature of the change, in each imaginary grid row through the map. Using an overlay, this information was developed and input into file BOUNDARY. Each record in the file contains:

a) the number of the row of interest (1 to NLAT);

b) the number of the district to which the map changes, in the row of interest, at and beyond the boundary location; and

c) the column location of the first point of the associated district (1 to NLON).

The program assumes that district 36 is assigned to all locations on the map outside of a C of E district (i.e., in oceans, foreign territories), and that district 99 is a flag used to indicate a transition to the next map row.

The program logic is simple. It loops over the rows of the map, reading from file BOUNDARY, and constructs the points in each row based on the input boundary information. As a final check, the map, transposed from the input orientation, is printed on the line printer. This was used to verify the input boundary information, as over 1650 records were required in the BOUNDARY file. The digitized map output is shown as Figure 6.2. This output information was written to a random access file <u>MAP</u> used by program MAPPER, described below, to compute Thiessen areas.

```
TYPE CAPPER
C       PROGRAM TO GENERATE INPUT MAP OF DISTRICTS
C       PREPARED BY DONALD GROSSMAN AND RAFAEL BRAS
C       PREPARED FOR NEW ENGLAND DISTRICT, ARMY CORPS OF ENGINEERS
C       TIM BUCKELEW, PROJECT OFFICER
C       MAY, 1982
C
C       VERSION OF 9 JUNE,1982
C
C       INPUT FILES
C
C               1       'BOUNDARY'      COORDINATES OF DISTRICT BOUNDARIES
C
C       OUTPUT FILES
C
C               2       'MAP'           NATIONAL MAP OF DISTRICT BOUNDARIES
C
C
C
        DIMENSION MDIS(224),MAP(136)
C
        COMMON/DUMMY/ ICODE(37)
C
        DATA ICODE /'A','B','C','D','E','F','G','H','I','J','K','L',
     A          'M','N','O','P','Q','R','S','T','U','V','W','X','Y',
     B          'Z','0','1','2','3','4','5','6','7','8','9',' '/
C
        NLON=224
        NLAT=136
        MDIS=36
        IBUG=0
        IMAP=0
C
C       OPEN BOUNDARY AND MAP FILES
C
        CALL OPEN(1,'BOUNDARY',1,IER)
        CALL FOPEN(2,'MAP',4)
C
C       JUMP TO MAP PRINT ONLY OCCURS HERE  IF IMAP=1
C
        IF (IMAP.EQ.1) GO TO 110
C
C
C       MAIN LOOP OVER THE ROWS OF THE MAP FOLLOWS
C
        IF (IBUG.GT.0) WRITE (10,9000)
9000    FORMAT (' BEFORE MAIN LOOP 100 OVER ROWS')
C
        DO 100 I=1,NLAT
C
        IREC=(I-1)*NLON+1
        CALL FSEEK(2,IREC)
C
C       LOOP OVER CHANGES IN BOUNDARIES
C
        IDIS1=NDIS+1
        MLON1=1
```

```
C
      DO 50 M=1,50
C
      IF (IBUG.GT.0) WRITE (10,9001)
9001  FORMAT (' READ OF BOUNDARY DATA OCCURRING')
C
      READ (1,1001) IDIS2,MLON2
1001  FORMAT(3X,I7,I8)
C
      IF (IBUG.GT.0) WRITE (10,9002) IDIS2,MLON2
9002  FORMAT (' READ OF BOUNDARY OCCURRED',2I8)
C
      IDIS2=IDIS2+1
      MLON21=MLON2-1
C
      DO 25 J=MLON1,MLON21
25    MDIS(J)=IDIS1
C
      IDIS1=IDIS2
      MLON1=MLON2
C
      IF (IDIS1.EQ.100) GO TO 75
C
50    CONTINUE
C
C     ERROR IN INPUT DATA DECK IF PROGRAM REACHES HERE
C
      WRITE (10,1002)
1002  FORMAT (1H1,'ERROR 1002: FAULTY INPUT')
C
      GO TO 999
C
C     HERE TO WRITE A MAP ROW
C
75    DO 80 J=1,224
80    WRITE (2,1003) MDIS(J)
1003  FORMAT(1X,I3)
C
      IF (IBUG.GT.0) WRITE (10,9003) MDIS(1)
9003  FORMAT (' WRITE TO MAP FILE TO HAVE OCCURRED',I3)
C
100   CONTINUE
C
C     SECTION TO PRINT TEST MAP FOLLOWS
C
110   IF (IBUG.GT.0) WRITE (10,9004)
9004  FORMAT (' BEFORE LOOP TO PRINT MAP ROWS')
C
      DO 200 I=1,MLON
C
      IF (IBUG.GT.0) WRITE (10,9005) I
9005  FORMAT (' IN LOOP OVER LONGITUDE',I8)
C
      II=MLON-I+1
C
      DO 125 J=1,MLAT
C
      IF (IBUG.GT.0) WRITE (10,9006) J
```

```
9006    FORMAT (' IN LOOP OVER LATITUDE',I8)
C
        IREC=(J-1)*NLON+II
C
        CALL FSEEK(2,IREC)
C
        READ (2,1004) MAP(J)
1004    FORMAT (I3)
C
        IF (IBUG.GT.0) WRITE (10,9007) IREC,MAP(J)
9007    FORMAT (' AFTER READ OF DISTRICT NUMBER',2I8)
C
        MDUM=MAP(J)
C
125     MAP(J)=ICODE(MDUM)
C
C       WRITE LINE OF MAP TO TERMINAL
C
        WRITE (10,1005) (MAP(J),J=1,132)
1005    FORMAT(132A1)
C
200     CONTINUE
C
C       END OF PROGRAM FOLLOWS
C
999     CONTINUE
C
        END
R
```

TYPE	BOUNDARY	
001	99	225
002	01	028
002	36	030
002	99	225
003	01	021
003	36	022
003	01	029
003	36	033
003	99	225
004	01	020
004	36	023
004	01	029
004	36	036
004	99	225
005	01	020
005	36	025
005	01	029
005	36	038
006	99	225
006	01	020
006	36	027
006	01	029
006	36	042
006	28	204
006	36	205
006	99	225
007	01	020
007	36	027
007	01	028
007	36	046
007	28	202
007	36	203
007	28	204
007	36	207
007	99	225
008	01	020
008	36	027
008	01	028
008	36	050
008	28	202
008	36	208
008	99	225
009	01	020
009	36	027
009	01	028
009	36	054
009	28	202
009	36	209
009	99	225
016	01	021
010	36	026
010	01	028
010	02	056
010	36	058
010	28	201
010	36	209
010	99	225
011	01	020
011	02	056
011	36	063
011	28	201
011	36	209
011	99	225
012	01	020
012	02	066
012	36	070
012	28	201
012	36	210
012	99	225
013	04	020
013	01	022
013	02	057
013	36	075
013	28	201
013	36	210
013	99	225
014	04	020
014	01	029
014	05	041
014	01	042
014	02	058
014	36	082
014	03	117
014	36	118
014	28	201
014	36	211
014	99	225
015	04	019
015	01	020
015	05	040
015	01	044
015	02	058
015	03	080
015	36	084
015	03	117
015	36	118
015	28	201
015	36	212
015	99	225
016	04	019
016	01	020
016	05	037
016	01	044
016	02	058
016	03	091
016	36	118
016	28	201
016	36	213
016	99	225
017	04	019
017	01	030
017	05	038
017	01	045
017	02	057
017	03	093

017	36	122
017	28	201
017	36	213
017	59	225
018	04	018
018	01	030
018	05	033
018	01	046
018	02	058
018	03	094
018	36	127
018	28	201
018	36	212
018	99	225
019	04	018
019	05	030
019	01	048
019	05	049
019	01	050
019	02	058
019	03	094
019	36	130
019	28	200
109	36	211
019	99	225
020	04	017
020	05	029
020	01	051
020	02	059
020	03	096
020	36	136
020	03	138
020	36	146
020	28	199
020	36	211
020	99	225
021	04	017
021	05	029
021	01	051
021	02	059
021	03	098
021	15	146
021	36	147
021	28	199
021	36	211
021	99	225
022	04	017
022	05	029
022	01	052
022	02	059
022	03	099
022	02	101
022	03	106
022	15	145
022	36	148
022	27	196
022	28	197
022	36	207

022	90	225
023	04	016
023	05	029
023	01	051
023	02	058
023	03	105
023	15	146
023	36	151
023	27	196
023	28	197
023	36	207
023	99	225
024	04	016
024	05	029
024	01	051
024	02	058
024	03	105
024	15	146
024	36	152
024	27	192
024	28	197
024	36	206
024	99	225
025	04	016
025	05	029
025	01	050
025	05	053
025	01	056
025	02	058
025	03	106
025	15	146
025	36	155
025	26	187
025	27	191
025	28	197
025	36	206
025	99	225
026	04	015
026	05	030
026	01	050
026	02	053
026	03	106
026	14	141
026	03	142
026	15	146
026	36	155
026	26	186
026	27	191
026	28	197
026	36	205
026	99	225
027	04	014
027	05	031
027	02	053
027	03	107
027	14	140
027	15	146
027	36	157

027	26	186
027	27	191
027	28	197
027	36	205
027	99	225
028	04	013
028	06	031
027	04	032
027	05	033
027	02	053
027	03	108
027	14	138
027	15	146
027	36	158
027	26	185
027	27	191
027	28	196
027	36	205
027	99	225
028	04	013
028	05	031
028	04	032
028	05	033
028	02	053
028	03	108
028	14	138
028	15	146
028	36	158
028	26	185
028	27	191
028	28	196
028	36	205
028	99	225
029	04	013
029	05	034
029	02	053
029	03	108
029	14	138
029	15	146
029	36	159
029	26	184
029	27	191
029	28	196
029	36	205
029	99	225
030	04	012
030	05	034
030	02	053
030	03	108
030	14	138
030	15	146
030	36	160
030	26	184
030	27	191
030	28	197
030	36	205
030	99	225
031	04	012

031	06	021
031	04	023
031	05	034
031	02	063
031	03	109
031	14	138
031	15	146
031	36	161
031	26	184
031	27	191
031	28	197
031	36	205
031	99	225
032	04	012
032	06	021
032	04	023
032	05	034
032	02	064
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109	09	078
109	10	092
109	00	108
109	10	110
109	00	113
109	21	185
109	36	139
109	21	141
109	36	142
109	21	143
109	36	144
109	22	161
109	35	162
109	35	169
109	36	179
109	99	225
110	09	078
110	10	092
110	00	106
110	21	185
110	36	144
110	35	170
110	36	180
110	99	225
111	00	078

111	36	086	115	99	225
111	09	089	116	10	095
111	10	092	116	00	107
111	00	108	116	36	118
111	21	125	116	35	172
111	36	126	116	36	183
111	21	127	116	99	225
111	36	132	117	10	095
111	21	133	117	00	107
111	36	142	117	36	113
111	35	172	117	00	114
111	36	181	117	36	115
111	99	225	117	35	172
112	09	079	117	36	183
112	36	085	117	99	225
112	10	092	118	10	096
112	00	109	118	00	106
112	36	119	118	36	113
112	00	120	118	35	174
112	36	123	118	36	184
112	21	129	118	99	225
112	36	133	119	10	096
112	21	134	119	00	105
112	36	140	119	36	111
112	21	141	119	35	174
112	36	143	119	36	185
112	35	172	119	99	226
112	36	182	120	10	097
112	99	225	120	00	105
113	09	081	120	36	110
113	36	085	120	35	174
113	10	093	120	36	185
113	00	109	120	99	225
113	36	119	121	10	098
113	21	135	121	00	104
113	36	140	121	36	109
113	21	142	121	35	175
113	36	144	121	36	186
113	35	173	121	99	225
113	36	182	122	10	099
113	99	225	122	00	102
114	09	082	122	36	109
114	36	084	122	35	175
114	10	094	122	36	176
114	00	107	122	35	177
114	36	120	122	36	186
114	21	137	122	99	225
114	36	138	123	10	099
114	21	139	123	00	102
114	36	140	123	36	109
114	35	173	123	35	177
114	36	182	123	36	186
114	99	225	123	99	225
115	10	094	124	10	100
115	00	108	124	00	102
115	36	119	124	36	108
115	36	173	124	35	176
115	36	182	124	36	186

124	99	225
125	10	100
125	00	101
125	36	108
125	35	177
125	36	186
125	39	225
126	00	100
126	36	108
126	35	178
126	36	185
126	99	225
127	00	101
127	36	108
127	35	179
127	36	185
127	99	225
128	00	101
128	36	108
128	35	180
128	36	184
128	99	225
129	00	103
129	36	109
129	35	181
129	36	184
129	99	225
130	00	105
130	36	103
130	99	225
131	00	108
131	36	109
131	99	225
132	99	225
133	99	225
134	99	225
135	99	225
136	99	225
137	99	225

R

B.3 Program MAPPER

Program MAPPER, written in standard Fortran IV was also implemented and executed in the NED Data General Nova 3-12. The program listing is included at the end of this section, followed by file COORD, which along with MAP, was the input for MAPPER. Also included is file AREAS, containing the output from program MAPPER.

As developed, the program is designed to use the digitized map representation of districts, and coordinate locations of rain gauge stations of interest, to compute the Thiessen areas of influence of the stations on each of the C of E districts. The other key controlling parameter, in addition to NLAT, NLON, and NDIS defined to characterize the digitized map, is:

NSTA - the number of precipitation measuring stations. As executed, the number of stations was set as NSTA = 255, representing the stations in the NWS TDL data set.

In addition to the MAP file generated by CAPPER, the other requisite input was the coordinates of the 255 rain gauge stations. Using the same overlay and base map used to define the digitized map, the coordinates of the rain gauges were defined using the 136 by 224 grid system. Each record of the COORD file contains:

a) Station Number (1 to NSTA);

b) The column number (longitude) of the station (ILON); and

c) The row number (latitude) of the station (ILAT).

Stations in the 255 location set which were out of the conterminous United States (i.e., those in Alaska, Hawaii, and Puerto Rico) and station numbers 75, 201, and 218 (for which the NWSTDL data was insufficient), were assigned coordinate locations ILAT = 136, ICON = 0, corresponding to a point in the extreme lower left corner of the map. This assignment insured that data from these station would not have any influence on the 36 C of E districts.

The program logic is relatively straightforward. For each of the 30,464 grid points in the map, the closest of the 255 precipitation stations was determined. This determination was made based on the known coordinates of the grid point and precipitation station. Also known from the MAP file was the district with which the map grid point was associated. Using this information, a file of numbers of grid points, by district, closest to each of the 255 rainfall stations is constructed. These data are then normalized by the total number of grid points (area) in each district. The resulting non-zero Thiessen areas of influence, and associated rainfall station numbers, were output into file AREAS. This file was constructed so that the first record contains the C of E district number, the next records contain non-zero station numbers and associated Thiessen areas, and all of the remaining records until record 51, contain zeros. File AREAS, shown at the end of this section, with minor editing for consistency, is the file FIL1 required by DCPMAIN.

```
TYPE MAPPER
C       PROGRAM TO PROCESS AREAL ATTRIBUTES OF PRECIPITATION STATION INFLUENCE
C       PREPARED BY DONALD GROSSMAN AND RAFAEL BRAS
C       PREPARED FOR NEW ENGLAND DIVISION, ARMY CORPS OF ENGINEERS
C       TIM BUCKELEW, PROJECT OFFICER
C       MAY, 1982
C
C       VERSION OF 9 JUNE, 1982
C
C       INPUT FILES
C
C               50      'COORD'         COORDINATES OF RAIN GAUGES
C               51      'MAP'           NATIONAL MAP OF DISTRICT BOUNDARIES
C
C       OUTPUT FILES
C
C               52      'AREAS'         THEISSEN AREAS BY DISTRICT
C
        DIMENSION ILON(255),ILAT(255),MDIS(224),XSUM(255,36),XAREA(36)
C
        NSTA=255
        NLON=224
        NLAT=136
        NDIS=36
        ZERO=0.0
        NZERO=0
C
C       INITIALIZATION OF XSUM ARRAY TO ZEROES
C
        DO 10 I=1,NSTA
        DO 10 J=1,NDIS
10      XSUM(I,J)=0.0
C
C       OPEN STATION DATA AND MAP FILES
C
        CALL OPEN (50,'COORD',1,IER)
        CALL FOPEN (51,'MAP',449)
C
C       INPUT STATION COORDINATES
C
        DO 20 I=1,NSTA
20      READ (50,1001) ILON(I),ILAT(I)
1001    FORMAT (2I4)
C
C       MAIN LOOP OVER THE ROWS OF  THE MAP FOLLOWS
C
        DO 100 I=1,NLAT
C
        IREC=(I-1)*NLON+1
        CALL FSEEK (51,IREC)
        READ (51,1002) (MDIS(J),J=1,NLON)
1002    FORMAT (224I2)
C
        DO 50 J=1,NLON
C
C       FIND CLOSEST PRECIPITATION STATION
C
        XDIST=999999.0
```

```
C
      DO 25 K=1,NSTA
C
      DIST=SQRT(FLOAT((NLAT-ILAT(K))**2+(NLON-ILON(K))**2))
C
      IF (DIST.GT.XDIST) GO TO 25
      XDIST=DIST
      INDEX=K
C
25    CONTINUE
C
C     INCREMENT NUMBERS OF POINTS INFLUENCED BY PRECIPITATION STATION
C
      XSUM(INDEX,MDIS(J))=XSUM(INDEX,MDIS(J))+1.0
C
50    CONTINUE
C
100   CONTINUE
C
C     CALCULATE FRACTION OF TOTAL DISTRICT AREA INFLUENCED BY STATION
C
      DO 200 J=1,NDIS
200   XAREA(J)=0.0
C
      DO 210 I=1,NSTA
      DO 210 J=1,NDIS
210   XAREA(J)=XAREA(J)+XSUM(I,J)
C
      DO 220 I=1,NSTA
      DO 220 J=1,NDIS
220   XSUM(I,J)=XSUM(I,J)/XAREA(J)
C
C     WRITE TO OUTPUT FILE
C
      CALL FOPEN (52,'AREAS',31)
      CALL FSEEK (52,1)

      DO 240 J=1,NDIS
C
      WRITE (52,1003) J
1003  FORMAT (I10)
C
      AREA=0.0
C
      DO 225 I=1,NSTA
225   AREA=AREA+XSUM(I,J)
C
      NDUM=0
C
      DO 230 I=1,NSTA
      IF (XSUM(I,J).LE.0.0) GO TO 230
C
      NDUM=NDUM+1
      XSUM(I,J)=XSUM(I,J)/AREA
C
      WRITE(52,1004) I,XSUM(I,J)
1004  FORMAT (I10,10X,F10.3)
C
```

```
230   CONTINUE
C
      NDUM1=NDUM+1
C
      DO 240 I=NDUM1,25
240   WRITE (52,1004) NZERO,ZERO
C
C
      END
P
```

TYPE	COORD	
001	051	000
002	168	078
003	166	093
004	163	085
005	177	095
006	157	084
007	167	064
008	169	082
009	172	066
010	110	097
011	109	072
012	127	110
013	139	098
014	128	066
015	120	065
016	187	040
017	178	044
018	001	136
019	180	110
020	177	124
021	179	133
022	185	127
023	178	114
024	174	117
025	185	122
026	143	113
027	110	117
028	140	110
029	108	130
030	105	113
031	108	122
032	118	112
033	182	074
034	179	074
035	176	059
036	181	067
037	192	067
038	192	051
039	187	065
040	177	068
041	187	058
042	188	082
043	191	052
044	145	097
045	176	064
046	166	087
047	163	089
048	152	091
049	169	073
050	181	091
051	176	079
052	158	082
053	176	086
054	175	104
055	163	077
056	138	084
057	148	105
058	155	096
059	151	078
060	152	106
061	129	104
062	124	098
063	107	109
064	110	103
065	111	096
066	099	098
067	129	086
068	121	083
069	104	086
070	108	083
071	114	080
072	136	107
073	108	063
074	098	067
075	001	136
076	136	067
077	125	074
078	115	065
079	208	019
080	207	008
081	196	046
082	176	039
083	195	046
084	194	036
085	191	048
086	204	034
087	199	039
088	192	028
089	201	031
090	186	050
091	205	026
092	204	037
093	184	036
094	185	036
095	189	043
096	184	046
097	145	049
098	167	048
099	163	056
100	159	041
101	155	052
102	156	043
103	138	044
104	143	044
105	150	042
106	138	056
107	154	025
108	150	050
109	149	034
110	171	049
111	172	044
112	168	051
113	141	036
114	127	028

115	111	026	173	095	050
116	122	017	174	075	034
117	131	041	175	071	028
118	123	035	176	075	044
119	135	052	177	088	040
120	126	040	178	040	049
121	105	033	179	054	052
122	131	056	180	032	047
123	123	052	181	042	035
124	106	056	182	031	032
125	107	039	183	062	018
126	124	045	184	060	023
127	114	054	185	053	015
128	113	048	186	053	020
129	112	043	187	035	022
130	132	036	188	054	041
131	001	136	189	043	015
132	093	113	190	033	050
133	001	136	191	046	055
134	001	136	192	016	046
135	001	136	193	019	026
136	088	099	194	016	034
137	104	103	195	024	011
138	090	091	196	022	018
139	070	099	197	025	025
140	091	084	198	020	021
141	083	083	199	027	010
142	071	083	200	031	016
143	080	060	201	001	136
144	092	063	202	014	026
145	066	063	203	001	136
146	066	074	204	001	136
147	023	083	205	001	136
148	032	061	206	001	136
149	042	057	207	001	136
150	022	073	208	001	136
151	051	068	209	001	136
152	052	096	210	001	136
153	022	077	211	001	136
154	038	073	212	001	136
155	023	081	213	001	136
156	048	089	214	001	136
157	024	052	215	001	136
158	026	082	216	001	136
159	055	082	217	081	065
160	037	091	218	001	136
161	012	058	219	068	093
162	016	055	220	081	068
163	011	059	221	047	066
164	016	058	222	020	066
165	015	075	223	188	055
166	098	026	224	196	075
167	096	015	225	195	053
168	081	054	226	185	058
169	068	043	227	193	054
170	096	055	228	165	106
171	099	038	229	158	062
172	065	050	230	159	058

231	147	069
232	152	060
233	159	067
234	154	067
235	138	060
236	120	104
237	103	066
238	079	018
239	068	014
240	089	019
241	019	014
242	021	004
243	199	042
244	187	024
245	197	046
246	139	024
247	139	048
248	175	052
249	160	048
250	144	049
251	161	044
252	158	032
253	151	043
254	133	047
255	128	048
P		

TYPE FILE

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29	0.142
30	0.009
31	0.193
32	0.288
63	0.060
236	0.064
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184	0.085
185	0.159
186	0.120
189	0.261
196	3.064

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141	0.007
142	0.062
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121	0.027
124	0.031
125	0.033
127	0.029
128	0.027
129	0.023
143	0.024
166	0.059
167	0.000
168	0.000
169	0.037
170	0.025

171	0.048	0	0.000
173	0.056	0	0.000
174	0.060	0	0.000
175	0.064	0	0.000
176	0.055	0	0.000
177	0.084	0	0.000
183	0.032	0	0.000
184	0.049	0	0.000
188	0.008	0	0.000
217	0.011	0	0.000
238	0.060	0	0.000
239	0.035	0	0.000
240	0.054	0	0.000
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0	0.000	195	0.016
0	0.000	196	0.097
4	0.000	197	0.166
103	0.014	198	0.078
113	0.010	199	0.003
114	0.135	200	0.040
115	0.197	202	0.051
116	0.087	241	0.029
117	0.038	0	0.000
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125	0.011	0	0.000
126	0.017	0	0.000
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130	0.083	0	0.000
166	0.004	0	0.000
167	0.074	0	0.000
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254	0.013	0	0.000
286	0.002	0	0.000

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165	0.076
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194	0.350
222	0.076
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149	0.032
150	0.028
151	0.067
153	0.008
157	0.064
159	0.008
161	0.003
162	0.030
164	0.028
169	0.010
172	0.076
178	0.037
179	0.086
180	0.053
188	0.014
190	0.037
191	0.049
192	0.052
194	0.002
221	0.035
222	0.051
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142	0.010
146	0.007
147	0.008
148	0.005
149	0.017
150	0.018
151	0.022
152	0.115
153	0.029
154	0.162
155	0.039
156	0.089
158	0.043
159	0.093
160	0.095
165	0.014
219	0.034
221	0.032
222	0.010
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10	0.000
74	0.066
132	0.075
136	0.114

138	0.009	66	0.123
139	0.159	132	0.131
140	0.001	136	0.104
141	0.111	137	0.100
142	0.153	138	0.000
144	0.018	141	0.007
146	0.022	236	0.000
217	0.024	0	0.000
219	0.113	0	0.000
220	0.142	0	0.000
237	0.004	0	0.000
0	0.000	0	0.000
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0	0.000	68	0.076
11	0.000	69	0.146
16	0.040	70	0.103
27	0.004	71	0.108
30	0.087	74	0.039
31	0.041	77	0.022
32	0.003	78	0.011
61	0.009	138	0.039
62	0.011	140	0.173
63	0.051	141	0.051
64	0.074	220	0.006
65	0.055	237	0.015

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76	0.059	0	0.000
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112	0.037
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94	0.133
98	0.095
99	0.084
110	0.024
111	0.071
112	0.071
244	0.090
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96	0.014
243	0.081
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91	0.141
92	0.063
243	0.051
245	0.003
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54	0.161
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0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
36	0.030
3	0.004
19	0.038
20	0.154
21	0.008
22	0.083
23	0.184
24	0.143
25	0.098
54	0.135
228	0.154
0	0.000

0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
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0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000
0	0.000

R

B.4 Program ZAPPER

Program ZAPPER written in standard Fortran 77 was implemented and executed on the NED Harris facilities. This computer system is supported by the Automatic Data Processing (ADP) Center at the New England Division Headquarters, and by 21 other C of E groups. The program listing is included at the end of this section, followed by a sample of the input file DATAIN, and sample output files ZAPPERF1 and ZAPPERF5.

Program ZAPPER is designed to process the NWSTDL rainfall data set to evaluate the number of events by class of depth interval, and the number of joint occurrences of rainfall or no rainfall between different stations, for all stations in the data set. The basic program logic is to obtain a day's rainfall data, evaluate the depth class interval for each station of interest to which the event is associated, evaluate the joint occurrence class of interest, up-date the event's counter, and record then on a seasonal basis. The key controlling parameters utilized in the program include:

NSTA = the number of rainfall data stations in the data set;

NSEAS = The number of seasons of interest; and

NDTS = the number of depth class intervals.

For the current analysis, data was available for NSTA = 255 stations, and this was evaluated for NSEAS = 4 seasons into NDTS = 8 depth class intervals.

By way of brief explanation, this program was originally configured for execution on the C of E Data General System. Because a large number of data points (255 stations by 8 depth classes and 255 by 255 stations for 4 joint daily occurrence classes -- all for 4 seasons) were to be accounted, and because the Data General System is only a 64K machine, the program originally kept a small subset of the number of events accumulators in core. Thus, in order to execute the program, frequent reads from and writes to disc were required. This might have been acceptable were a small data set to be analyzed. However, the 9 years of 6-hourly data for 255 stations meant an analysis of 3287 days of record, or nearly 1.2 million data points. Experimental runs indicated that hundreds of days of execution time would have been required on the Data General. Accordingly, the program was moved to the faster and larger Harris System, and successfully executed on this system in 4.25 hours of CPU time.

The program requires as input a file called DATAIN which was constructed to contain rainfall records on a 6-hourly basis for each of 255 stations. The first record of each group in the file contains the rainfall data line, namely:

a) year;

b) month;

c) day; and

d) hour

of the event of interest. This is followed by rainfall data for each of the 255 stations of interest, written into 22 records. The file was accessed sequentially for the 9 years of records.

After initializing the key parameters, numbers of events accumulators, and opening the input and output files, the program loops over the days of input data record. The 6-hour data is accumulated into 24-hour data, the event of interest. Then for each station, the depth interval of interest, namely;

1. 0.00 - 0.01 inches ("no" rain)
2. 0.01 - 0.50 inches
3. 0.50 - 1.00 inches
4. 1.00 - 1.25 inches
5. 1.25 - 1.50 inches
6. 1.50 - 2.00 inches
7. 2.00 - 3.00 inches
8. 3.00+ inches

is determined. The number of events by interval is maintained for each station, on a seasonal basis. These data are recorded in the ZAPPERF1, ZAPPER F2, ZAPPERF3, and ZAPPERF4 for the four seasons, respectively. Seasons are defined as follows:

1 = December, January, February

2 = March, April, May

3 = June, July, August

4 = September, October, November

Then for each station i, the numbers of events in each of four classes of joint occurrence with other stations j, are determined, namely:

1. no rainfall at station i and no rainfall at station j;
2. no rainfall at station i and rainfall at station j;
3. rainfall at station i and no rainfall at station j; and
4. rainfall at station i and rainfall at station j.

This provides the information needed to evaluate the joint probability of occurrence of events between stations. Because of the symmetry involved, if the numbers of events, in the same class, between some pair of stations i and j are known, it is not necessary to evaluate the events for stations j and i, the same pair of stations in reverse order. Information on the joint occurrence of events is stored in files ZAPPERF5, ZAPPERF6, ZAPPERF7, and ZAPPERF8 for the four seasons 1, 2, 3, and 4, respectively. As the program steps over time, only the current season of events accumulations is kept in core.

The output station files ZAPPERF1 to ZAPPERF4 contain in each record the following data:

1. station number (1 to 255)
2. season number (1 to 4)
3. number of events for each of the depth interval classes.

There are 255 records in each of the four files. A sample from file ZAPPERF1 is shown at the end of this section.

The output cross station files ZAPPERF5 to ZAPPERF8 contain in each record the following:

1. first station number (I = 1 to 255)
2. second station number (J = I + 1 to 255)

```
      TYPE ALL
C
C     PROGRAM ZAPPER
C
C     PROGRAM TO PROCESS PRECIPITATION DATA FILE
C     PREPARED BY DONALD GROSSMAN AND RAFAEL BRAS
C     PREPARED FOR NEW ENGLAND DIVISION, ARMY CORPS OF ENGINEERS
C     TIM BUCKELEW, PROJECT OFFICER
C     JULY, 1982
C
C     VERSION OF 9 JULY, 1982
C
C     INPUT FILES
C
C         19      DATAIN      NWSTDL RAINFALL DATA FILE
C
C     OUTPUT FILES
C
C         11      F1          RAINFALL PROBABILITIES - WINTER
C         12      F2          RAINFALL PROBABILITIES - SPRING
C         13      F3          RAINFALL PROBABILITIES - SUMMER
C         14      F4          RAINFALL PROBABILITIES - FALL
C         15      F5          CORRELATIONS - WINTER
C         16      F6          CORRELATIONS - SPRING
C         17      F7          CORRELATIONS - SUMMER
C         18      F8          CORRELATIONS - FALL
C
C***********************************************************************
C
      INTEGER XSM,XDM
      INTEGER*6 ITIME
      COMMON/DUMMY1/ XSM(255,8),XDM(255,255,4),PPT(255),PPX(255)
      DIMENSION ISEAS(12),BREAK(7)
      CHARACTER*2 XICH(8)
      CHARACTER PREFIX*14,FILENM*16
C
C     INITIALIZATION OF RUN CONSTANTS AND LIMITS
C
      CALL BTIME
      PREFIX='7232HYDRZAPPER'
      ICNT=0
      NSTA=255
      NSTAX=255
      NSEAS=4
      NPTS=8
      NPTS1=NPTS-1
      IBUG=0
      ISTOP=0
C
      DATA ISEAS/1,1,2,2,2,3,3,3,4,4,4,1/
      DATA BREAK/0.01,0.5,1.00,1.25,1.50,2.00,3.00/
      DATA XICH/'F1','F2','F3','F4','F5','F6','F7','F8'/
C
      ISTART=1
      IEND=36500
      INIT=0
C
C
      DO 10 I=1,NSTA
```

```
      DO 10 J=1,NPTS
10    XSM(I,J)=0.0
C
      IF (IBUG.GT.0) WRITE(3,8999)
8999  FORMAT(' INITIALIZATION OF STATION ARRAY COMPLETED')
C
      DO 25 I=1,NSTA
      DO 25 J=1,NSTA
      DO 25 L=1,4
25    XDM(I,J,L)=0.0
C
      IF (IBUG.GT.0) WRITE(3,9000)
9000  FORMAT(' INITIALIZATION OF CROSS STATION ARRAYS COMPLETED')
C
C     ESTABLISH FILES FOR ARRAYS
C
      DO 50 K=1,NSEAS
C
      ICH1=K+10
C
      FILENM=PREFIX//XICH(ICH1-10)
C
      IF (IBUG.GT.0) WRITE(3,9001) ICH1,FILENM
9001  FORMAT(' AT OPEN STATEMENT FOR FILE ',I2,'=',A16)
C
      OPEN(UNIT=ICH1,FILE=FILENM,ACCESS='DIRECT',
     1     FORM='FORMATTED',RECL=100)
C
      IF (INIT.NE.0) GO TO 35
C
      DO 30 I=1,NSTA
30    WRITE(ICH1,1001,REC=I) I,K,(XSM(I,L),L=1,NPTS)
C
C
      IF (IBUG.GT.0) WRITE (3,9002)
9002  FORMAT (' PAST WRITE OF ZERO FILE')
C
35    CONTINUE
C
      ICH2=14+K
C
      FILENM=PREFIX//XICH(ICH2-10)
C
      IF (IBUG.GT.0) WRITE(3,9003) ICH2,FILENM
9003  FORMAT (' AT OPEN STATEMENT FOR FILE ',I2,'=',A16)
C
      OPEN(UNIT=ICH2,FILE=FILENM,ACCESS='DIRECT',
     1     FORM='FORMATTED',RECL=70)
C
      IF (INIT.NE.0) GO TO 50
C
      DO 40 I=1,NSTA
      I1=I+1
      DO 40 J=I1,NSTA
      IREC=(I-1)*(2*NSTA-I)/2+(J-I)
40    WRITE(ICH2,1002,REC=IREC) I,J,K,(XDM(I,J,L),L=1,4)
C
      IF (IBUG.GT.0) WRITE(3,9004)
9004  FORMAT (' PAST WRITE OF ZERO FILE')
C
```

```
50    CONTINUE
C
1001  FORMAT(2I10,8I10)
1002  FORMAT(3I10,4I10)
C
C     OPEN INPUT FILE
C
45    CONTINUE
C
      OPEN(UNIT=19,FILE='7232HYDRDATAIN  ',ACCESS='SEQUENTIAL',
     1     FORM='FORMATTED')
      OPEN(UNIT=20,FILE='7232HYDRDAYSAVER',ACCESS='SEQUENTIAL',
     1     FORM='FORMATTED')
C
C     ----------------------------------------------------------------
C
C     MAIN LOOP BACK POINT IS HERE
C
C     ----------------------------------------------------------------
C
      DO 200 IDAY=ISTART,IEND
C
C     INITIALIZATION OF PRECIPITATION AMOUNTS
C
      DO 55 I=1,NSTA
55    PPT(I)=0.0
C
C     ACCUMULATION OF PRECIPITATION AMOUNTS
C
      DO 57 J=1,4
C
      IF (IBUG.GT.1) WRITE(3,9010) IDAY,J
9010  FORMAT (' PRIOR TO READ OF DAY = ',I5,' TIMESTEP = ',I1)
C
      READ(19,1005,END=997) IYR,IMO,IDA,IHR,(PPX(I),I=1,NSTAX)
1005  FORMAT(4I2/(12F6.3))
C
      DO 57 I=1,NSTA
57    PPT(I)=PPT(I)+PPX(I)
C
      IF (IBUG.GT.0) WRITE(3,9011) (PPT(I),I=1,NSTA)
9011  FORMAT (' AFTER READ OF DAY = ',10F6.3)
C
C
C     CODE TO READ FILES AS REQUIRED AND TEST FOR END OF FILE
C
      GO TO 998
C
C     FLAG TO TERMINATE RUN
C
997   ISTOP=1
998   CONTINUE
C
C     TEST FOR NEW SEASON AND START OR STOP OF RUN
C
      IF(K.EQ.ISEAS(IMO).AND.IDAY.NE.ISTART.AND.ISTOP.EQ.0) GO TO 65
C
      IF (IDAY.EQ.ISTART) GO TO 60
C
C     HERE TO WRITE CURRENT STATION FILES
```

```
C
      DO 58 I=1,NSTA
58    WRITE(ICH1,1001,REC=I) I,K,(XSM(I,L),L=1,NPTS)
C
      DO 59 I=1,NSTA
      I1=I+1
      DO 59 J=I1,NSTA
      IREC=(I-1)*(2*NSTA-I)/2+(J-I)
      IF (IBUG.GT.1) WRITE(3,1002) I,J,K,(XDM(I,J,L),L=1,4)
59    WRITE(ICH2,1002,REC=IREC) I,J,K,(XDM(I,J,L),L=1,4)
C
      IF (ISTOP.EQ.1) GO TO 999
C
C     HERE TO READ NEW STATION FILES
C
60    K=ISEAS(IMO)
      ICH1=K+10
      ICH2=K+14
C
      IF (IBUG.GT.0) WRITE(3,9012) ICH1
9012  FORMAT (' PRIOR TO READ OF FILE = ',I2)
C
      DO 61 I=1,NSTA
61    READ(ICH1,1001,REC=I) IDUM,KDUM,(XSM(I,L),L=1,NPTS)
C
      IF (IBUG.GT.0) WRITE(3,9013) ICH2
9013  FORMAT (' PRIOR TO READ OF FILE = ',I2)
C
      DO 62 I=1,NSTA
      I1=I+1
      DO 62 J=I1,NSTA
      IREC=(I-1)*(2*NSTA-I)/2+(J-I)
      READ(ICH2,1002,REC=IREC) IDUM,JDUM,KDUM,(XDM(I,J,L),L=1,4)
62    IF (IBUG.GT.1) WRITE(3,1002)
     1   IDUM,JDUM,KDUM,(XDM(I,J,L),L=1,4)
C
65    CONTINUE
C
      IF (IBUG.GT.0) WRITE(3,9014)
9014  FORMAT (' BEFORE BEGINNING OF LOOP OVER STATIONS')
C
C
C     MAIN LOOP OVER THE STATIONS
C
C
      DO 150 I=1,NSTA
C
      I1=I+1
C
      IF(PPT(I).GT.99.998) GO TO 150
C
      DO 70 L=1,NPTS1
70    IF(PPT(I).LT.BREAK(L)) XSM(I,L)=XSM(I,L)+1.0
C
      XSM(I,NPTS)=XSM(I,NPTS)+1.0
C
C     INSERT CODE TO COMPUTE MOMENTS HERE IF DESIRED
C
      DO 100 J=I1,NSTA
C
```

```
      IF(IBUG.GT.1) WRITE(3,9030) I,J,PPT(I),PPT(J)
 9030 FORMAT(2I10,2F10.3)
C
      IF(PPT(J).GT.99.998) GO TO 100
C
      IF(PPT(I).GT.0.001) GO TO 80
      IF(PPT(J).GT.0.001) GO TO 75
      XDM(I,J,1)=XDM(I,J,1)+1
      GO TO 99
 75   XDM(I,J,2)=XDM(I,J,2)+1
      GO TO 99
 80   IF(PPT(J).GT.0.001) GO TO 85
      XDM(I,J,3)=XDM(I,J,3)+1
      GO TO 99
 85   XDM(I,J,4)=XDM(I,J,4)+1
C
 99   IF(IBUG.GT.1) WRITE(3,9031) I,J,PPT(I),PPT(J),(XDM(I,J,L),L=1,4)
 9031 FORMAT(2I10,2F10.3,4I10)
C
 100  CONTINUE
C
 150  CONTINUE
C
C     WRITE MESSAGE ON LINE PRINTER SIGNALING END OF DAY
C
      CALL ETIME2(ITIME)
      WRITE(20,1006) IDAY,ITIME
 1006 FORMAT(' COMPLETED DAY ',I7,' AT ELAPSED CPU TIME = ',I10)
C
C
C
C     RETURN TO LOOP BACK POINT OR BRANCH TO TERMINATE RUN
C
C     -----------------------------------------------------------------------
C
C
      IF (IDAY.EQ.IEND) GO TO 997
C
C
C
 200  CONTINUE
C
C
 999  CONTINUE
C
C
C
C     ***********************************************************************
C
      END
EOT..
E>
```

```
LIST DATAIN
===> LIST DATAIN
1 7210 1 6
2  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
3  0.000 0.000 0.000 0.004 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
4  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00099.999
5  0.000 0.000 0.000 0.000 0.000 0.004 0.000 0.000 0.000 0.000 0.000 0.000
6  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
7  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
8  0.000 0.00099.999 0.000 0.000 0.000 0.150 0.110 0.000 0.000 0.000 0.000
9  0.000 0.000 0.000 0.000 0.000 0.000 0.004 0.000 0.000 0.000 0.000 0.000
10  0.000 0.004 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.004 0.000
11  0.000 0.004 0.000 0.000 0.000 0.004 0.000 0.004 0.000 0.000 0.000 0.000
12  0.00099.999 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.320 0.000
13  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
14  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
15  0.040 0.000 0.000 0.000 0.000 0.000 0.000 0.00099.999 0.000 0.000 0.000
16  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
17  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.004 0.000 0.000
18  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00099.999 0.000 0.004 0.004
19  0.000 0.004 0.010 0.010 0.004 0.000 0.004 0.000 0.004 0.004 0.030 0.004
20  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.170 0.000 0.00099.999 0.000
21  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
22  0.000 0.004 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
23  0.00099.999 0.000
24 7210 112
25  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
26  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.020 0.000 0.000 0.000 0.000
27  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
28  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
29  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
30  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
31  0.000 0.00099.999 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
32  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
33  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.020 0.000 0.010 0.000
34  0.000 0.004 0.050 0.000 0.040 0.004 0.000 0.000 0.000 0.000 0.000 0.000
35  0.00099.999 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.340 0.000
36  0.000 0.040 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
37  0.000 0.000 0.000 0.000 0.000 0.004 0.000 0.000 0.000 0.000 0.000 0.000
38  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00099.999 0.000 0.000 0.000
39  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.004
40  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.004 0.000 0.000
41  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.004 0.00099.999 0.000 0.000 0.030
42  0.000 0.000 0.010 0.004 0.000 0.004 0.020 0.000 0.000 0.000 0.070 0.004
43  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.00099.999 0.000
44  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
45  0.000 0.060 0.000 0.000 0.000 0.000 0.004 0.000 0.000 0.004 0.000 0.000
46  0.000 0.000 0.000
47 7210 118
48  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
49  0.000 0.000 0.000 0.000 0.000 0.004 0.000 0.180 0.000 0.000 0.370 0.240
50  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
51  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
52  0.000 0.000 0.000 0.000 0.000 0.004 0.000 0.000 0.000 0.000 0.000 0.000
53  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
54  0.000 0.00099.999 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
55  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
56  0.000 0.000 0.000 0.030 0.000 0.020 0.000 0.000 0.030 0.000 0.060 0.004
57  0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
58  0.00099.999 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
```

XE
===> XE

Sample of ZAPPERF1

1	1	593	761	794	801	803	805	810	810
2	1	531	751	785	797	801	807	812	812
3	1	558	733	775	791	799	804	808	812
4	1	557	734	788	795	798	805	811	811
5	1	576	750	796	802	803	810	811	811
6	1	502	718	773	787	796	807	810	811
7	1	390	761	800	806	807	808	810	810
8	1	547	731	784	796	801	807	811	811
9	1	339	769	802	806	810	812	812	812
10	1	628	784	800	804	808	810	811	811
11	1	632	794	807	808	809	812	812	812
12	1	548	738	776	784	794	803	810	811
13	1	526	715	766	782	789	799	808	812
14	1	525	776	803	806	807	808	809	809
15	1	588	793	805	806	807	808	808	809
16	1	273	770	802	810	811	812	812	812
17	1	191	752	798	802	804	805	806	806
18	1	369	777	800	801	804	807	809	809
19	1	604	766	792	800	804	808	811	812
20	1	650	772	789	793	797	800	803	803
21	1	648	789	799	803	805	809	810	810
22	1	618	783	798	803	807	809	812	812
23	1	616	774	798	805	807	809	812	812
24	1	619	767	800	804	805	808	810	811
25	1	585	769	792	798	802	805	809	811
26	1	379	486	514	517	524	527	531	534
27	1	558	777	798	803	806	809	810	811
28	1	542	724	765	777	780	793	808	812
29	1	594	795	806	809	809	810	811	811
30	1	594	792	806	806	811	811	812	812
31	1	590	792	804	809	809	811	811	811
32	1	542	751	787	799	802	805	811	811
33	1	548	736	791	805	810	811	811	812
34	1	535	752	791	799	807	811	812	812
35	1	298	767	807	810	811	811	811	811
36	1	420	592	619	627	634	635	635	635
37	1	517	744	799	806	808	812	812	812
38	1	520	741	785	796	802	807	810	810
39	1	526	743	791	797	806	810	811	811
40	1	522	757	795	806	807	809	809	809
41	1	553	758	792	803	810	811	812	812
42	1	542	734	784	793	804	808	810	812
43	1	518	746	786	796	802	812	812	812
44	1	539	719	766	777	783	798	807	811
45	1	368	765	804	807	811	812	812	812
46	1	542	726	783	793	801	809	811	812
47	1	532	726	771	788	798	805	809	811
48	1	521	724	774	784	791	797	804	804
49	1	464	754	803	807	809	811	812	812
50	1	564	750	792	803	805	810	810	811
51	1	543	747	787	797	801	809	811	811
52	1	506	724	781	791	800	809	811	812
53	1	542	735	781	791	796	802	812	812
54	1	594	755	795	800	803	809	812	812
55	1	485	735	789	798	802	808	810	810
56	1	529	729	775	787	794	805	809	812
57	1	534	731	778	788	796	806	808	812
58	1	534	731	778	789	797	804	811	812

XE
===> XE

Sample of ZAPPERF5

1	2	1	272	268	133	137
1	3	1	318	222	168	102
1	4	1	304	236	170	99
1	5	1	322	217	182	88
1	6	1	288	251	120	150
1	7	1	180	358	95	175
1	8	1	318	221	163	107
1	9	1	154	386	80	190
1	10	1	406	134	137	132
1	11	1	370	170	120	150
1	12	1	313	227	124	145
1	13	1	291	249	141	129
1	14	1	268	271	99	169
1	15	1	331	207	127	142
1	16	1	89	451	44	226
1	17	1	64	472	30	238
1	18	1	147	391	83	186
1	19	1	317	223	190	80
1	20	1	385	149	220	47
1	21	1	343	197	200	68
1	22	1	336	204	178	92
1	23	1	333	207	202	88
1	24	1	330	209	205	65
1	25	1	310	230	179	90
1	26	1	207	115	138	73
1	27	1	331	209	104	165
1	28	1	297	243	134	136
1	29	1	298	242	182	107
1	30	1	361	179	112	158
1	31	1	332	207	138	132
1	32	1	326	214	113	156
1	33	1	303	237	158	112
1	34	1	317	223	158	112
1	35	1	134	406	73	197
1	36	1	248	181	120	84
1	37	1	293	247	148	122
1	38	1	270	269	147	122
1	39	1	292	247	153	117
1	40	1	275	263	132	137
1	41	1	279	261	146	124
1	42	1	313	227	162	108
1	43	1	265	275	148	122
1	44	1	307	232	144	126
1	45	1	168	372	87	183
1	46	1	313	227	150	120
1	47	1	296	243	139	131
1	48	1	297	238	135	132
1	49	1	242	298	117	153
1	50	1	302	237	173	97
1	51	1	315	224	159	111
1	52	1	300	240	131	139
1	53	1	312	228	183	107
1	54	1	312	228	185	85
1	55	1	266	272	123	147
1	56	1	288	252	120	150
1	57	1	315	225	144	126
1	58	1	315	225	153	117
1	59	1	257	283	112	156

3. season number (1 to 4)

4. number of events for each of 4 joint occurrence classes.

There are 32,385 records in each of the four files (the number of points in the upper half of a 255 by 255 matrix).

These 8 files contain numbers of events and are generated as a intermediate product. The information of interest for DCPMAIN is in fact the probabilities of events. Program TAPPER converts the numbers of events into probabilities of occurrence, as described in the section that follows.

B.5 Program TAPPER

Program TAPPER written in standard Fortran 77 was implemented and executed on the N.E.D. Harris system, described in the previous section. The program listing is included at the end of this section, followed by sample output from files TAPPERF1 and TAPPERF5.

Program TAPPER is a relatively simple program designed to take the output files from program ZAPPER and normalize the numbers of events to probabilities of occurrence of events of interest.

The program reads each of the station files ZAPPER1 to ZAPPER4, determines the total number of events for each station in each season, and then computes and writes the TAPPERF1 to TAPPERF4 which contain the following data in each record:

1. station number (1 to 255)
2. season number (1 to 4)

3. probability of no rain

4. probability of rain in depth interval 2 to 8 (see Section B.4), given that it rained.

These files TAPPERF1, TAPPERF2, TAPPERF3, and TAPPERF4 are exactly the input files F251, F252, F253, and F254 needed as input to DCPMAIN. A sample is included at the end of this section. Each file has 255 records.

In an analogous manner, ZAPPERF5 to ZAPPERF8 were read in and normalized to combine in each record:

1. first station number (I = 1 to 255)

2. second station number (J = I + 1 to 255)

3. season number (1 to 4)

4. probability of events in each of 4 joint occurrence classes.

These output files, TAPPERF5, TAPPERF6, TAPPERF7, and TAPPERF8 are exactly the input files F351, F352, F353, and F354 needed as input to DCPMAIN. A sample is included at the end of this section. Each file has 32,385 records.

```
TYPE ALL

C
C     PROGRAM TAPPER
C
C     PROGRAM TO PROCESS PRECIPITATION DATA FILE
C     PREPARED BY DONALD GROSSMAN AND RAFAEL BRAS
C     PREPARED FOR NEW ENGLAND DIVISION, ARMY CORPS OF ENGINEERS
C     TIM BUCKELEW, PROJECT OFFICER
C     AUGUST, 1982
C
C     VERSION OF 9 AUGUST, 1982
C
C     INPUT FILES
C
C         11      F1         RAINFALL PROBABILITIES - WINTER
C         12      F2         RAINFALL PROBABILITIES - SPRING
C         13      F3         RAINFALL PROBABILITIES - SUMMER
C         14      F4         RAINFALL PROBABILITIES - FALL
C         15      F5         CORRELATIONS - WINTER
C         16      F6         CORRELATIONS - SPRING
C         17      F7         CORRELATIONS - SUMMER
C         18      F8         CORRELATIONS - FALL
C
C*****************************************************************************
C
      INTEGER XSM,XDM
      INTEGER*6 ITIME
      COMMON/DUMMY1/ XSM(8),XDM(255,4),PPT,PPX(255)
      COMMON/DUMMY2/ ASM(8),ADM(255,4)
      CHARACTER*2 XICH(8)
      CHARACTER PREFIX1*14,PREFIX2*14,FILEA*16,FILEB*16
C
C     INITIALIZATION OF RUN CONSTANTS AND LIMITS
C
      CALL BTIME
      PREFIX1='7232HYDRZAPPER'
      PREFIX2='7232HYDRTAPPER'
      NSTA=255
      NSEAS=4
      NPTS=8
      IBUG=0
C
      DATA XICH/'F1','F2','F3','F4','F5','F6','F7','F8'/
C
C
C
C
C     ESTABLISH FILES FOR ARRAYS
C
      DO 50 K=1,NSEAS
C
      ICH1=K+10
      ICH3=K+20
C
      FILEA=PREFIX1//XICH(ICH1-10)
      FILEB=PREFIX2//XICH(ICH1-10)
C
C
      OPEN(UNIT=ICH1,FILE=FILEA,ACCESS='DIRECT',
```

```
     1     FORM='FORMATTED',RECL=100)
C
      OPEN(UNIT=ICH3,FILE=FILER,ACCESS='SEQUENTIAL',
     1     FORM='FORMATTED')
C
C
C
C
C
      ICH2=14+K
      ICH4=24+K
C
      FILEA=PREFIX1//XICH(ICH2-10)
      FILEB=PREFIX2//XICH(ICH2-10)
C
C
      OPEN(UNIT=ICH2,FILE=FILEA,ACCESS='DIRECT',
     1     FORM='FORMATTED',RECL=70)
C
      OPEN(UNIT=ICH4,FILE=FILER,ACCESS='SEQUENTIAL',
     1     FORM='FORMATTED')
C
C
C
50    CONTINUE
1001  FORMAT(2I10,8I10)
1002  FORMAT(3I10,4I10)
1003  FORMAT(2I10,8F10.3)
1004  FORMAT(3I10,4F10.3)
C
C
C     ------------------------------------------------------------
C
C     END OF FILE POST PROCESSING FOLLOWS THIS POINT
C
C     ------------------------------------------------------------
C
C     LOOP OVER SEASONS
C
      DO 300 K=1,4
C
C     INITIALIZE EVENTS ACCUMULATORS
C
C     READ EXISTING STATION FILE
C
      ICH1=K+10
      ICH3=K+20
C
      DO 240 I=1,NSTA
      READ(ICH1,1001,REC=I) IDUM,KDUM,(XSM(L),L=1,NPTS)
      PPT=XSM(NPTS)
      IF (PPT.EQ.0.0) PPT=0.00001
C
C
C     WRITE EXISTING STATION FILE
C
      ASM(1)=FLOAT(XSM(1))/PPT
C
      DO 230 J=2,NPTS
230   ASM(J)=FLOAT(XSM(J)-XSM(J-1))/(PPT-XSM(1))
```

```
      IF (IBUG.GT.1) WRITE(3,8999) I,ICH3
8999  FORMAT (' BEFORE WRITE OF STATION = ',I3,' TO FILE = ',I2)
C
240   WRITE(ICH3,1003) I,K,(ASM(L),L=1,NPTS)
C
      IF (IBUG.GT.0) WRITE(3,9001) ICH3
9001  FORMAT (' AFTER WRITE OF FILE = ',I3)
C     READ EXISTING CROSS STATION FILE
C
      ICH2=K+14
      ICH4=K+24
C
      DO 260 I=1,NSTA
      I1=I+1
      DO 250 J=I1,NSTA
      IREC=(I-1)*(2*NSTA-I)/2+(J-I)
      READ(ICH2,1002,REC=IREC) IDUM,JDUM,KDUM,(XDM(J,L),L=1,4)
      PPX(J)=0.0
      DO 250 L=1,4
250   PPX(J)=PPX(J)+XDM(J,L)
C
      IF (IBUG.GT.0) WRITE (3,9006) ICH2
9006  FORMAT (' AFTER READ OF FILE = ',I3)
C
      DO 251 J=I1,NSTA
251   IF (PPX(J).EQ.0.0) PPX(J)=0.0001
C
      IF (IBUG.GT.0) WRITE (3,9007)
9007  FORMAT (' AFTER DO 251 CONTINUE LOOP')
C     WRITE EXISTING CROSS STATION FILE
C
      DO 260 J=I1,NSTA
      IF(IBUG.GT.0) WRITE (3,9008)
9008  FORMAT (' AFTER START OF FINAL DO 260 LOOP')
      DO 255 L=1,4
255   ADM(J,L)=FLOAT(XDM(J,L))/PPX(J)
C
      IF (IBUG.GT.0) WRITE(3,9005)
9005  FORMAT (' BEFORE WRITE OF CROSS STATION FILE')
C
      WRITE(ICH4,1004) I,J,K,(ADM(J,L),L=1,4)
260   CONTINUE
C
300   CONTINUE
C
C
C     ***********************************************************************
C
      END
EOT;.
E>
```

LI TAPPERF1
===> LI TAPPERF1

1	1	1	0.732	0.774	0.152	0.032	0.009	0.009	0.023	0.000
2	2	1	0.654	0.783	0.121	0.043	0.014	0.021	0.018	0.000
3	3	1	0.687	0.689	0.165	0.063	0.031	0.020	0.016	0.016
4	4	1	0.687	0.697	0.213	0.028	0.012	0.028	0.024	0.000
5	5	1	0.710	0.740	0.196	0.026	0.004	0.030	0.004	0.000
6	6	1	0.619	0.699	0.178	0.045	0.029	0.036	0.010	0.003
7	7	1	0.481	0.883	0.093	0.014	0.002	0.002	0.005	0.000
8	8	1	0.674	0.697	0.201	0.045	0.019	0.023	0.015	0.000
9	9	1	0.417	0.909	0.070	0.008	0.008	0.004	0.000	0.000
10	10	1	0.772	0.854	0.086	0.022	0.022	0.011	0.005	0.000
11	11	1	0.778	0.900	0.072	0.006	0.006	0.017	0.000	0.000
12	12	1	0.676	0.722	0.144	0.030	0.038	0.034	0.027	0.004
13	13	1	0.648	0.661	0.178	0.056	0.024	0.035	0.031	0.014
14	14	1	0.649	0.884	0.095	0.011	0.004	0.004	0.004	0.000
15	15	1	0.727	0.928	0.054	0.005	0.005	0.005	0.000	0.005
16	16	1	0.336	0.922	0.059	0.015	0.002	0.002	0.000	0.000
17	17	1	0.237	0.912	0.075	0.007	0.003	0.002	0.002	0.000
18	18	1	0.456	0.927	0.052	0.002	0.007	0.007	0.005	0.000
19	19	1	0.744	0.779	0.125	0.038	0.019	0.019	0.014	0.005
20	20	1	0.809	0.797	0.111	0.026	0.026	0.020	0.020	0.000
21	21	1	0.800	0.870	0.062	0.025	0.012	0.025	0.006	0.000
22	22	1	0.761	0.851	0.077	0.026	0.021	0.010	0.015	0.000
23	23	1	0.759	0.806	0.122	0.036	0.010	0.010	0.015	0.000
24	24	1	0.763	0.771	0.172	0.021	0.005	0.016	0.010	0.005
25	25	1	0.721	0.814	0.102	0.027	0.018	0.013	0.018	0.009
26	26	1	0.710	0.690	0.181	0.019	0.045	0.019	0.026	0.019
27	27	1	0.688	0.866	0.083	0.020	0.012	0.012	0.004	0.004
28	28	1	0.667	0.674	0.152	0.044	0.011	0.048	0.056	0.015
29	29	1	0.732	0.926	0.051	0.014	0.000	0.005	0.005	0.000
30	30	1	0.732	0.908	0.064	0.000	0.023	0.000	0.005	0.000
31	31	1	0.727	0.914	0.054	0.023	0.000	0.009	0.000	0.000
32	32	1	0.668	0.777	0.134	0.045	0.011	0.011	0.022	0.000
33	33	1	0.675	0.712	0.208	0.053	0.019	0.004	0.000	0.004
34	34	1	0.659	0.783	0.141	0.029	0.029	0.014	0.004	0.000
35	35	1	0.367	0.914	0.078	0.006	0.002	0.000	0.000	0.000
36	36	1	0.661	0.800	0.126	0.037	0.033	0.005	0.000	0.000
37	37	1	0.637	0.769	0.186	0.024	0.007	0.014	0.000	0.000
38	38	1	0.642	0.762	0.152	0.038	0.021	0.017	0.010	0.000
39	39	1	0.649	0.761	0.168	0.021	0.032	0.014	0.004	0.000
40	40	1	0.645	0.819	0.132	0.038	0.003	0.007	0.000	0.000
41	41	1	0.681	0.792	0.131	0.042	0.027	0.004	0.004	0.000
42	42	1	0.667	0.711	0.185	0.033	0.041	0.015	0.007	0.007
43	43	1	0.638	0.776	0.136	0.034	0.020	0.034	0.000	0.000
44	44	1	0.665	0.662	0.173	0.040	0.022	0.055	0.033	0.015
45	45	1	0.453	0.894	0.088	0.007	0.009	0.002	0.000	0.000
46	46	1	0.667	0.681	0.211	0.037	0.030	0.030	0.007	0.004
47	47	1	0.656	0.695	0.161	0.061	0.036	0.025	0.014	0.007
48	48	1	0.648	0.717	0.177	0.035	0.025	0.021	0.025	0.000
49	49	1	0.571	0.833	0.141	0.011	0.006	0.006	0.003	0.000
50	50	1	0.695	0.753	0.170	0.045	0.008	0.020	0.000	0.004
51	51	1	0.670	0.761	0.149	0.037	0.015	0.030	0.007	0.000
52	52	1	0.623	0.712	0.186	0.033	0.029	0.029	0.007	0.003
53	53	1	0.667	0.715	0.170	0.037	0.019	0.022	0.037	0.000
54	54	1	0.732	0.739	0.183	0.023	0.014	0.028	0.014	0.000
55	55	1	0.599	0.769	0.166	0.028	0.012	0.018	0.006	0.000
56	56	1	0.651	0.707	0.163	0.042	0.025	0.039	0.014	0.011
57	57	1	0.658	0.709	0.169	0.036	0.029	0.036	0.007	0.014
58	58	1	0.658	0.709	0.169	0.040	0.029	0.025	0.025	0.004

59	59	1	0.593	0.770	0.127	0.027	0.042	0.018	0.012	0.003
60	60	1	0.702	0.703	0.188	0.029	0.004	0.033	0.025	0.017
61	61	1	0.661	0.647	0.222	0.033	0.026	0.026	0.026	0.020
62	62	1	0.667	0.719	0.159	0.037	0.030	0.037	0.019	0.000
63	63	1	0.730	0.836	0.128	0.018	0.009	0.005	0.005	0.000
64	64	1	0.751	0.837	0.094	0.010	0.025	0.025	0.010	0.000
65	65	1	0.724	0.833	0.119	0.048	0.000	0.000	0.000	0.000
66	66	1	0.831	0.883	0.095	0.007	0.007	0.007	0.000	0.000
67	67	1	0.689	0.720	0.148	0.044	0.052	0.016	0.020	0.000
68	68	1	0.740	0.820	0.109	0.028	0.028	0.009	0.005	0.000
69	69	1	0.829	0.892	0.065	0.022	0.007	0.007	0.007	0.000
70	70	1	0.787	0.884	0.081	0.012	0.006	0.006	0.012	0.000
71	71	1	0.776	0.830	0.110	0.033	0.011	0.016	0.000	0.000
72	72	1	0.672	0.707	0.132	0.045	0.030	0.045	0.030	0.011
73	73	1	0.786	0.954	0.040	0.000	0.000	0.006	0.000	0.000
74	74	1	0.813	0.961	0.039	0.000	0.000	0.000	0.000	0.000
75	75	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	76	1	0.633	0.892	0.071	0.020	0.007	0.007	0.003	0.000
77	77	1	0.691	0.865	0.092	0.016	0.016	0.004	0.008	0.000
78	78	1	0.755	0.929	0.040	0.010	0.005	0.005	0.010	0.000
79	79	1	0.630	0.827	0.116	0.024	0.017	0.010	0.003	0.003
80	80	1	0.472	0.881	0.096	0.016	0.005	0.000	0.002	0.000
81	81	1	0.649	0.754	0.165	0.035	0.007	0.028	0.007	0.004
82	82	1	0.262	0.931	0.057	0.005	0.003	0.002	0.000	0.002
83	83	1	0.651	0.784	0.138	0.035	0.007	0.021	0.011	0.004
84	84	1	0.584	0.855	0.116	0.012	0.009	0.009	0.000	0.000
85	85	1	0.602	0.777	0.155	0.031	0.019	0.012	0.006	0.000
86	86	1	0.631	0.773	0.130	0.033	0.023	0.020	0.020	0.000
87	87	1	0.629	0.774	0.126	0.027	0.030	0.037	0.007	0.000
88	88	1	0.441	0.945	0.038	0.011	0.002	0.004	0.000	0.000
89	89	1	0.656	0.792	0.133	0.043	0.014	0.014	0.004	0.000
90	90	1	0.637	0.776	0.141	0.038	0.024	0.021	0.000	0.000
91	91	1	0.633	0.741	0.158	0.044	0.017	0.020	0.013	0.007
92	92	1	0.611	0.747	0.146	0.044	0.022	0.013	0.028	0.000
93	93	1	0.309	0.948	0.045	0.005	0.000	0.002	0.000	0.000
94	94	1	0.336	0.939	0.050	0.009	0.000	0.002	0.000	0.000
95	95	1	0.511	0.889	0.088	0.005	0.003	0.008	0.005	0.003
96	96	1	0.563	0.847	0.085	0.025	0.023	0.011	0.006	0.003
97	97	1	0.542	0.914	0.066	0.007	0.003	0.007	0.003	0.000
98	98	1	0.374	0.939	0.047	0.004	0.004	0.006	0.000	0.000
99	99	1	0.488	0.920	0.065	0.007	0.002	0.002	0.002	0.000
100	100	1	0.464	0.942	0.048	0.009	0.000	0.000	0.000	0.000
101	101	1	0.525	0.914	0.078	0.005	0.003	0.000	0.000	0.000
102	102	1	0.444	0.944	0.042	0.009	0.004	0.000	0.000	0.000
103	103	1	0.608	0.947	0.050	0.000	0.000	0.003	0.000	0.000
104	104	1	0.525	0.922	0.055	0.010	0.010	0.003	0.000	0.000
105	105	1	0.372	0.955	0.030	0.008	0.006	0.002	0.000	0.000
106	106	1	0.594	0.921	0.048	0.018	0.009	0.003	0.000	0.000
107	107	1	0.308	0.970	0.028	0.002	0.000	0.000	0.000	0.000
108	108	1	0.413	0.916	0.063	0.004	0.011	0.006	0.000	0.000
109	109	1	0.334	0.975	0.023	0.002	0.000	0.000	0.000	0.000
110	110	1	0.374	0.937	0.055	0.006	0.000	0.000	0.002	0.000
111	111	1	0.305	0.940	0.048	0.004	0.002	0.004	0.004	0.000
112	112	1	0.408	0.921	0.069	0.004	0.006	0.000	0.000	0.000
113	113	1	0.578	0.959	0.032	0.006	0.000	0.003	0.000	0.000
114	114	1	0.517	0.977	0.021	0.000	0.003	0.000	0.000	0.000
115	115	1	0.580	0.988	0.012	0.000	0.000	0.000	0.000	0.000
116	116	1	0.509	0.995	0.003	0.000	0.003	0.000	0.000	0.000
117	117	1	0.690	0.960	0.040	0.000	0.000	0.000	0.000	0.000
118	118	1	0.623	0.984	0.010	0.007	0.000	0.000	0.000	0.000

119	119	1	0.632	0.923	0.050	0.013	0.013	0.000	0.000	0.000
120	120	1	0.637	0.976	0.020	0.003	0.000	0.000	0.000	0.000
121	121	1	0.707	0.996	0.004	0.000	0.000	0.000	0.000	0.000
122	122	1	0.734	0.939	0.053	0.000	0.000	0.000	0.009	0.000
123	123	1	0.679	0.938	0.046	0.000	0.008	0.008	0.000	0.000
124	124	1	0.772	0.989	0.005	0.005	0.000	0.000	0.000	0.000
125	125	1	0.752	0.980	0.015	0.000	0.005	0.000	0.000	0.000
126	126	1	0.764	0.936	0.059	0.000	0.005	0.000	0.000	0.000
127	127	1	0.762	0.963	0.037	0.000	0.000	0.000	0.000	0.000
128	128	1	0.714	0.978	0.022	0.000	0.000	0.000	0.000	0.000
129	129	1	0.714	0.987	0.013	0.000	0.000	0.000	0.000	0.000
130	130	1	0.635	0.986	0.007	0.007	0.000	0.000	0.000	0.000
131	131	1	0.452	0.718	0.142	0.032	0.023	0.020	0.027	0.038
132	132	1	0.836	0.926	0.065	0.000	0.009	0.000	0.000	0.000
133	133	1	0.684	0.836	0.086	0.020	0.012	0.023	0.012	0.012
134	134	1	0.653	0.869	0.071	0.014	0.007	0.014	0.021	0.004
135	135	1	0.523	0.884	0.049	0.021	0.000	0.018	0.018	0.010
136	136	1	0.860	0.956	0.035	0.000	0.000	0.009	0.000	0.000
137	137	1	0.837	0.886	0.091	0.015	0.000	0.000	0.008	0.000
138	138	1	0.840	0.969	0.031	0.000	0.000	0.000	0.000	0.000
139	139	1	0.856	0.983	0.017	0.000	0.000	0.000	0.000	0.000
140	140	1	0.828	1.000	0.000	0.000	0.000	0.000	0.000	0.000
141	141	1	0.888	0.978	0.022	0.000	0.000	0.000	0.000	0.000
142	142	1	0.837	0.962	0.038	0.000	0.000	0.000	0.000	0.000
143	143	1	0.793	0.970	0.018	0.000	0.006	0.000	0.006	0.000
144	144	1	0.800	0.981	0.019	0.000	0.000	0.000	0.000	0.000
145	145	1	0.779	0.994	0.006	0.000	0.000	0.000	0.000	0.000
146	146	1	0.835	1.000	0.000	0.000	0.000	0.000	0.000	0.000
147	147	1	0.790	0.635	0.229	0.047	0.018	0.035	0.024	0.012
148	148	1	0.862	0.972	0.028	0.000	0.000	0.000	0.000	0.000
149	149	1	0.756	0.980	0.015	0.005	0.000	0.000	0.000	0.000
150	150	1	0.805	0.930	0.051	0.013	0.000	0.000	0.006	0.000
151	151	1	0.823	0.957	0.029	0.014	0.000	0.000	0.000	0.000
152	152	1	0.837	0.879	0.121	0.000	0.000	0.000	0.000	0.000
153	153	1	0.884	0.936	0.064	0.000	0.000	0.000	0.000	0.000
154	154	1	0.874	0.882	0.118	0.000	0.000	0.000	0.000	0.000
155	155	1	0.798	0.640	0.207	0.049	0.043	0.043	0.018	0.000
156	156	1	0.857	0.897	0.069	0.034	0.000	0.000	0.000	0.000
157	157	1	0.766	0.932	0.068	0.000	0.000	0.000	0.000	0.000
158	158	1	0.784	0.817	0.103	0.040	0.017	0.017	0.006	0.000
159	159	1	0.845	0.990	0.010	0.000	0.000	0.000	0.000	0.000
160	160	1	0.912	0.891	0.109	0.000	0.000	0.000	0.000	0.000
161	161	1	0.688	0.796	0.132	0.034	0.017	0.013	0.009	0.000
162	162	1	0.707	0.728	0.187	0.038	0.038	0.004	0.004	0.000
163	163	1	0.676	0.734	0.167	0.034	0.027	0.023	0.015	0.000
164	164	1	0.715	0.853	0.113	0.022	0.000	0.013	0.000	0.000
165	165	1	0.688	0.597	0.242	0.065	0.048	0.032	0.016	0.000
166	166	1	0.568	1.000	0.000	0.000	0.000	0.000	0.000	0.000
167	167	1	0.627	0.976	0.020	0.003	0.000	0.000	0.000	0.000
168	168	1	0.783	0.983	0.006	0.011	0.000	0.000	0.000	0.000
169	169	1	0.821	0.959	0.041	0.000	0.000	0.000	0.000	0.000
170	170	1	0.782	0.977	0.023	0.000	0.000	0.000	0.000	0.000
171	171	1	0.754	1.000	0.000	0.000	0.000	0.000	0.000	0.000
172	172	1	0.823	0.979	0.021	0.000	0.000	0.000	0.000	0.000
173	173	1	0.777	0.978	0.022	0.000	0.000	0.000	0.000	0.000
174	174	1	0.697	1.000	0.000	0.000	0.000	0.000	0.000	0.000
175	175	1	0.715	0.978	0.017	0.000	0.004	0.000	0.000	0.000
176	176	1	0.727	1.000	0.000	0.000	0.000	0.000	0.000	0.000
177	177	1	0.709	0.996	0.004	0.000	0.000	0.000	0.000	0.000
178	178	1	0.733	0.981	0.014	0.005	0.000	0.000	0.000	0.000

179	179	1	0.629	0.963	0.033	0.000	0.000	0.003	0.000	0.000
180	180	1	0.740	0.995	0.005	0.000	0.000	0.000	0.000	0.000
181	181	1	0.602	0.978	0.022	0.000	0.000	0.000	0.000	0.000
182	182	1	0.549	0.947	0.053	0.000	0.000	0.000	0.000	0.000
183	183	1	0.659	0.989	0.011	0.000	0.000	0.000	0.000	0.000
184	184	1	0.692	0.996	0.004	0.000	0.000	0.000	0.000	0.000
185	185	1	0.467	0.984	0.016	0.000	0.000	0.000	0.000	0.000
186	186	1	0.504	0.988	0.012	0.000	0.000	0.000	0.000	0.000
187	187	1	0.564	0.963	0.034	0.003	0.000	0.000	0.000	0.000
188	188	1	0.604	0.994	0.006	0.000	0.000	0.000	0.000	0.000
189	189	1	0.529	0.958	0.042	0.000	0.000	0.000	0.000	0.000
190	190	1	0.818	0.993	0.007	0.000	0.000	0.000	0.000	0.000
191	191	1	0.809	1.000	0.000	0.000	0.000	0.000	0.000	0.000
192	192	1	0.642	0.759	0.145	0.031	0.034	0.024	0.007	0.000
193	193	1	0.429	0.737	0.155	0.039	0.024	0.019	0.022	0.004
194	194	1	0.564	0.915	0.062	0.014	0.008	0.000	0.000	0.000
195	195	1	0.337	0.756	0.156	0.035	0.024	0.022	0.006	0.000
196	196	1	0.390	0.826	0.119	0.024	0.016	0.010	0.004	0.000
197	197	1	0.684	0.984	0.008	0.008	0.000	0.000	0.000	0.000
198	198	1	0.423	0.784	0.156	0.017	0.028	0.011	0.004	0.000
199	199	1	0.417	0.820	0.131	0.028	0.013	0.006	0.002	0.000
200	200	1	0.665	0.963	0.033	0.000	0.000	0.004	0.000	0.000
201	201	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
202	202	1	0.424	0.675	0.201	0.045	0.028	0.022	0.024	0.004
203	203	1	0.261	0.596	0.266	0.058	0.040	0.026	0.012	0.002
204	204	1	0.375	0.897	0.091	0.004	0.008	0.000	0.000	0.000
205	205	1	0.347	0.589	0.236	0.051	0.051	0.042	0.026	0.006
206	206	1	0.617	0.990	0.006	0.003	0.000	0.000	0.000	0.000
207	207	1	0.251	0.934	0.048	0.005	0.002	0.008	0.003	0.000
208	208	1	0.270	0.993	0.007	0.000	0.000	0.000	0.000	0.000
209	209	1	0.693	0.996	0.004	0.000	0.000	0.000	0.000	0.000
210	210	1	0.666	0.978	0.022	0.000	0.000	0.000	0.000	0.000
211	211	1	0.666	0.978	0.022	0.000	0.000	0.000	0.000	0.000
212	212	1	0.641	1.000	0.000	0.000	0.000	0.000	0.000	0.000
213	213	1	0.676	1.000	0.000	0.000	0.000	0.000	0.000	0.000
214	214	1	0.614	0.994	0.006	0.000	0.000	0.000	0.000	0.000
215	215	1	0.618	1.000	0.000	0.000	0.000	0.000	0.000	0.000
216	216	1	0.721	1.000	0.000	0.000	0.000	0.000	0.000	0.000
217	217	1	0.784	0.994	0.006	0.000	0.000	0.000	0.000	0.000
218	218	1	0.774	1.000	0.000	0.000	0.000	0.000	0.000	0.000
219	219	1	0.896	0.979	0.021	0.000	0.000	0.000	0.000	0.000
220	220	1	0.853	1.000	0.000	0.000	0.000	0.000	0.000	0.000
221	221	1	0.791	0.958	0.036	0.006	0.000	0.000	0.000	0.000
222	222	1	0.730	0.881	0.087	0.027	0.005	0.000	0.000	0.000
223	223	1	0.664	0.766	0.158	0.029	0.029	0.007	0.011	0.000
224	224	1	0.646	0.707	0.185	0.042	0.010	0.035	0.010	0.010
225	225	1	0.655	0.786	0.136	0.043	0.011	0.018	0.007	0.000
226	226	1	0.663	0.806	0.121	0.037	0.029	0.004	0.000	0.004
227	227	1	0.717	0.784	0.216	0.000	0.000	0.000	0.000	0.000
228	228	1	0.714	0.638	0.159	0.065	0.039	0.043	0.030	0.026
229	229	1	0.540	0.903	0.062	0.011	0.016	0.003	0.005	0.000
230	230	1	0.506	0.910	0.072	0.010	0.005	0.000	0.002	0.000
231	231	1	0.607	0.865	0.097	0.016	0.009	0.006	0.006	0.000
232	232	1	0.550	0.882	0.085	0.018	0.014	0.003	0.000	0.000
233	233	1	0.542	0.849	0.105	0.019	0.005	0.005	0.011	0.005
234	234	1	0.590	0.839	0.109	0.015	0.012	0.018	0.006	0.000
235	235	1	0.602	0.901	0.074	0.009	0.000	0.012	0.003	0.000
236	236	1	0.696	0.739	0.151	0.041	0.024	0.012	0.020	0.012
237	237	1	0.847	0.919	0.065	0.008	0.008	0.000	0.000	0.000
238	238	1	0.688	1.000	0.000	0.000	0.000	0.000	0.000	0.000

239	239	1	0.712	0.996	0.004	0.000	0.000	0.000	0.000	0.000
240	240	1	0.637	0.997	0.003	0.000	0.000	0.000	0.000	0.000
241	241	1	0.313	0.693	0.187	0.038	0.020	0.048	0.013	0.002
242	242	1	0.280	0.582	0.211	0.067	0.045	0.036	0.038	0.022
243	243	1	0.644	0.735	0.170	0.032	0.028	0.025	0.007	0.004
244	244	1	0.457	0.949	0.042	0.005	0.002	0.002	0.000	0.000
245	245	1	0.656	0.756	0.158	0.025	0.036	0.014	0.007	0.004
246	246	1	0.348	0.978	0.017	0.002	0.002	0.000	0.000	0.000
247	247	1	0.591	0.921	0.063	0.009	0.003	0.003	0.000	0.000
248	248	1	0.380	0.934	0.050	0.008	0.006	0.002	0.000	0.000
249	249	1	0.473	0.916	0.073	0.005	0.007	0.000	0.000	0.000
250	250	1	0.555	0.920	0.050	0.019	0.011	0.000	0.000	0.000
251	251	1	0.483	0.931	0.062	0.002	0.005	0.000	0.000	0.000
252	252	1	0.340	0.976	0.017	0.006	0.000	0.002	0.000	0.000
253	253	1	0.411	0.941	0.040	0.013	0.000	0.006	0.000	0.000
254	254	1	0.644	0.956	0.027	0.009	0.009	0.000	0.000	0.000
255	255	1	0.703	0.959	0.025	0.008	0.004	0.004	0.000	0.000

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LIST TAPPERF2
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1	1	2	0.729	0.844	0.134	0.009	0.013	0.000	0.000	0.000
2	2	2	0.637	0.673	0.170	0.057	0.010	0.053	0.027	0.010
3	3	2	0.692	0.686	0.192	0.035	0.024	0.020	0.039	0.004
4	4	2	0.679	0.718	0.150	0.045	0.045	0.026	0.015	0.000
5	5	2	0.702	0.713	0.166	0.053	0.020	0.020	0.016	0.012
6	6	2	0.596	0.674	0.153	0.039	0.048	0.036	0.027	0.024
7	7	2	0.542	0.828	0.135	0.011	0.013	0.011	0.003	0.000
8	8	2	0.642	0.693	0.152	0.041	0.044	0.037	0.027	0.007
9	9	2	0.521	0.826	0.144	0.015	0.003	0.010	0.000	0.003
10	10	2	0.702	0.690	0.184	0.061	0.016	0.029	0.012	0.008
11	11	2	0.644	0.786	0.129	0.024	0.034	0.017	0.010	0.000
12	12	2	0.709	0.701	0.149	0.041	0.021	0.021	0.025	0.041
13	13	2	0.653	0.599	0.209	0.038	0.035	0.056	0.038	0.024
14	14	2	0.581	0.771	0.145	0.023	0.023	0.020	0.017	0.000
15	15	2	0.625	0.777	0.136	0.042	0.013	0.016	0.006	0.010
16	16	2	0.498	0.887	0.089	0.014	0.002	0.005	0.002	0.000
17	17	2	0.468	0.880	0.099	0.005	0.002	0.011	0.002	0.000
18	18	2	0.559	0.844	0.093	0.019	0.019	0.005	0.005	0.014
19	19	2	0.764	0.718	0.149	0.041	0.026	0.041	0.021	0.005
20	20	2	0.848	0.736	0.136	0.032	0.000	0.032	0.040	0.024
21	21	2	0.825	0.766	0.124	0.028	0.007	0.034	0.028	0.014
22	22	2	0.772	0.723	0.133	0.043	0.016	0.037	0.037	0.011
23	23	2	0.767	0.756	0.098	0.052	0.031	0.016	0.041	0.005
24	24	2	0.818	0.742	0.152	0.033	0.020	0.020	0.020	0.013
25	25	2	0.744	0.726	0.118	0.042	0.057	0.019	0.019	0.019
26	26	2	0.734	0.529	0.193	0.067	0.050	0.059	0.084	0.017
27	27	2	0.714	0.789	0.093	0.013	0.051	0.030	0.017	0.008
28	28	2	0.693	0.661	0.114	0.063	0.020	0.043	0.055	0.043
29	29	2	0.844	0.760	0.116	0.016	0.016	0.031	0.039	0.023
30	30	2	0.674	0.778	0.137	0.030	0.007	0.026	0.015	0.007
31	31	2	0.779	0.754	0.087	0.027	0.060	0.055	0.005	0.011
32	32	2	0.680	0.717	0.162	0.030	0.026	0.023	0.034	0.008
33	33	2	0.680	0.736	0.170	0.053	0.015	0.019	0.004	0.004
34	34	2	0.664	0.759	0.176	0.018	0.014	0.025	0.004	0.004
35	35	2	0.483	0.873	0.106	0.014	0.007	0.000	0.000	0.000
36	36	2	0.665	0.759	0.139	0.046	0.014	0.028	0.009	0.005
37	37	2	0.657	0.708	0.190	0.028	0.042	0.011	0.018	0.004
38	38	2	0.621	0.744	0.185	0.038	0.010	0.016	0.006	0.000
39	39	2	0.653	0.798	0.118	0.031	0.028	0.021	0.000	0.003
40	40	2	0.628	0.779	0.146	0.019	0.023	0.016	0.006	0.010
41	41	2	0.647	0.798	0.151	0.024	0.017	0.003	0.007	0.000
42	42	2	0.682	0.730	0.171	0.046	0.019	0.017	0.015	0.000
43	43	2	0.618	0.750	0.184	0.025	0.009	0.022	0.009	0.000
44	44	2	0.657	0.567	0.165	0.081	0.025	0.067	0.074	0.021
45	45	2	0.530	0.830	0.139	0.013	0.008	0.008	0.003	0.000
46	46	2	0.687	0.678	0.170	0.047	0.040	0.033	0.014	0.018
47	47	2	0.649	0.679	0.179	0.041	0.031	0.024	0.028	0.017
48	48	2	0.630	0.618	0.197	0.039	0.046	0.036	0.043	0.020
49	49	2	0.594	0.789	0.149	0.027	0.009	0.018	0.006	0.003
50	50	2	0.693	0.728	0.157	0.055	0.016	0.024	0.016	0.004
51	51	2	0.658	0.714	0.170	0.035	0.039	0.025	0.014	0.004
52	52	2	0.634	0.659	0.185	0.043	0.026	0.058	0.023	0.007
53	53	2	0.699	0.643	0.233	0.044	0.024	0.024	0.032	0.000
54	54	2	0.727	0.673	0.186	0.044	0.027	0.027	0.013	0.031
55	55	2	0.607	0.702	0.178	0.058	0.022	0.012	0.018	0.009
56	56	2	0.602	0.666	0.152	0.070	0.033	0.027	0.040	0.012
57	57	2	0.654	0.622	0.157	0.035	0.021	0.059	0.073	0.031
58	58	2	0.667	0.591	0.217	0.051	0.047	0.047	0.033	0.014

59	59	2	0.586	0.717	0.163	0.020	0.023	0.035	0.026	0.015
60	60	2	0.711	0.624	0.148	0.076	0.025	0.046	0.055	0.025
61	61	2	0.672	0.616	0.199	0.046	0.026	0.026	0.060	0.026
62	62	2	0.674	0.674	0.174	0.048	0.033	0.037	0.015	0.019
63	63	2	0.675	0.755	0.115	0.041	0.019	0.037	0.015	0.019
64	64	2	0.684	0.720	0.149	0.050	0.034	0.019	0.017	0.008
65	65	2	0.648	0.781	0.094	0.000	0.031	0.031	0.062	0.000
66	66	2	0.776	0.800	0.130	0.038	0.016	0.016	0.000	0.000
67	67	2	0.663	0.618	0.185	0.065	0.029	0.055	0.022	0.025
68	68	2	0.627	0.731	0.166	0.036	0.023	0.026	0.013	0.008
69	69	2	0.736	0.752	0.147	0.037	0.023	0.018	0.014	0.009
70	70	2	0.678	0.720	0.142	0.037	0.034	0.043	0.017	0.004
71	71	2	0.640	0.661	0.168	0.047	0.034	0.060	0.023	0.007
72	72	2	0.670	0.659	0.158	0.044	0.022	0.022	0.051	0.044
73	73	2	0.644	0.803	0.139	0.027	0.010	0.017	0.003	0.000
74	74	2	0.677	0.824	0.109	0.026	0.019	0.011	0.007	0.004
75	75	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	76	2	0.584	0.817	0.122	0.017	0.017	0.015	0.009	0.003
77	77	2	0.594	0.755	0.158	0.036	0.015	0.018	0.012	0.006
78	78	2	0.628	0.773	0.149	0.039	0.016	0.016	0.003	0.003
79	79	2	0.633	0.832	0.121	0.020	0.010	0.017	0.000	0.000
80	80	2	0.527	0.882	0.102	0.008	0.008	0.000	0.000	0.000
81	81	2	0.617	0.767	0.155	0.038	0.013	0.016	0.013	0.000
82	82	2	0.486	0.899	0.085	0.007	0.005	0.005	0.000	0.000
83	83	2	0.617	0.763	0.158	0.022	0.016	0.022	0.019	0.000
84	84	2	0.576	0.855	0.103	0.020	0.009	0.014	0.000	0.000
85	85	2	0.604	0.811	0.125	0.024	0.021	0.012	0.006	0.000
86	86	2	0.623	0.814	0.131	0.022	0.010	0.019	0.003	0.000
87	87	2	0.618	0.769	0.165	0.022	0.009	0.016	0.019	0.000
88	88	2	0.537	0.888	0.094	0.008	0.008	0.003	0.000	0.000
89	89	2	0.633	0.832	0.115	0.023	0.020	0.007	0.003	0.000
90	90	2	0.615	0.808	0.112	0.035	0.016	0.022	0.006	0.000
91	91	2	0.597	0.787	0.147	0.018	0.009	0.021	0.012	0.006
92	92	2	0.623	0.772	0.138	0.029	0.029	0.022	0.010	0.000
93	93	2	0.539	0.921	0.071	0.005	0.000	0.000	0.000	0.003
94	94	2	0.506	0.873	0.093	0.015	0.010	0.007	0.002	0.000
95	95	2	0.546	0.864	0.112	0.016	0.005	0.000	0.003	0.000
96	96	2	0.572	0.827	0.108	0.034	0.014	0.011	0.006	0.000
97	97	2	0.558	0.806	0.130	0.021	0.021	0.014	0.004	0.004
98	98	2	0.514	0.883	0.097	0.010	0.005	0.002	0.002	0.000
99	99	2	0.566	0.849	0.126	0.011	0.006	0.006	0.003	0.000
100	100	2	0.571	0.862	0.104	0.011	0.011	0.006	0.006	0.000
101	101	2	0.581	0.865	0.101	0.020	0.009	0.006	0.000	0.000
102	102	2	0.561	0.871	0.096	0.017	0.014	0.003	0.000	0.000
103	103	2	0.597	0.829	0.117	0.027	0.009	0.009	0.009	0.000
104	104	2	0.558	0.849	0.107	0.005	0.014	0.016	0.005	0.003
105	105	2	0.585	0.857	0.111	0.015	0.009	0.006	0.003	0.000
106	106	2	0.570	0.784	0.140	0.028	0.022	0.020	0.006	0.000
107	107	2	0.576	0.872	0.094	0.020	0.006	0.006	0.003	0.000
108	108	2	0.537	0.809	0.131	0.029	0.010	0.008	0.013	0.000
109	109	2	0.622	0.877	0.084	0.026	0.006	0.006	0.000	0.000
110	110	2	0.505	0.856	0.122	0.012	0.002	0.005	0.002	0.000
111	111	2	0.501	0.845	0.131	0.010	0.007	0.002	0.005	0.000
112	112	2	0.515	0.872	0.092	0.012	0.007	0.012	0.003	0.000
113	113	2	0.613	0.844	0.122	0.022	0.006	0.003	0.003	0.000
114	114	2	0.593	0.917	0.065	0.009	0.003	0.000	0.006	0.000
115	115	2	0.687	0.900	0.081	0.000	0.012	0.004	0.000	0.004
116	116	2	0.667	0.895	0.087	0.007	0.000	0.011	0.000	0.000
117	117	2	0.665	0.814	0.120	0.022	0.015	0.018	0.007	0.004
118	118	2	0.626	0.900	0.074	0.010	0.006	0.003	0.006	0.000

119	119	2	0.574	0.813	0.114	0.026	0.003	0.034	0.009	0.003
120	120	2	0.587	0.874	0.094	0.026	0.003	0.000	0.003	0.000
121	121	2	0.684	0.888	0.096	0.015	0.000	0.000	0.000	0.000
122	122	2	0.667	0.797	0.138	0.014	0.014	0.036	0.000	0.000
123	123	2	0.607	0.830	0.096	0.043	0.012	0.009	0.009	0.000
124	124	2	0.660	0.811	0.129	0.014	0.021	0.011	0.014	0.000
125	125	2	0.682	0.856	0.122	0.011	0.004	0.008	0.000	0.000
126	126	2	0.675	0.755	0.174	0.038	0.015	0.011	0.004	0.004
127	127	2	0.669	0.804	0.119	0.037	0.015	0.019	0.007	0.000
128	128	2	0.653	0.826	0.125	0.021	0.021	0.007	0.000	0.000
129	129	2	0.644	0.850	0.122	0.014	0.010	0.003	0.000	0.000
130	130	2	0.640	0.805	0.123	0.024	0.027	0.010	0.007	0.003
131	131	2	0.172	0.750	0.146	0.029	0.015	0.022	0.023	0.015
132	132	2	0.791	0.828	0.127	0.015	0.015	0.015	0.000	0.000
133	133	2	0.680	0.943	0.042	0.000	0.000	0.011	0.004	0.000
134	134	2	0.605	0.936	0.031	0.018	0.003	0.009	0.000	0.003
135	135	2	0.393	0.920	0.048	0.006	0.004	0.012	0.006	0.004
136	136	2	0.852	0.836	0.131	0.016	0.000	0.016	0.000	0.000
137	137	2	0.780	0.802	0.121	0.033	0.000	0.027	0.016	0.000
138	138	2	0.781	0.867	0.099	0.006	0.011	0.006	0.011	0.000
139	139	2	0.924	0.984	0.016	0.000	0.000	0.000	0.000	0.000
140	140	2	0.739	0.884	0.065	0.014	0.014	0.014	0.009	0.000
141	141	2	0.847	0.863	0.121	0.008	0.000	0.008	0.000	0.000
142	142	2	0.837	0.963	0.037	0.000	0.000	0.000	0.000	0.000
143	143	2	0.690	0.871	0.109	0.004	0.004	0.008	0.000	0.004
144	144	2	0.694	0.846	0.095	0.012	0.012	0.028	0.008	0.000
145	145	2	0.757	0.955	0.045	0.000	0.000	0.000	0.000	0.000
146	146	2	0.838	0.990	0.010	0.000	0.000	0.000	0.000	0.000
147	147	2	0.864	0.786	0.125	0.036	0.018	0.036	0.000	0.000
148	148	2	0.851	0.951	0.049	0.000	0.000	0.000	0.000	0.000
149	149	2	0.692	0.949	0.047	0.004	0.000	0.000	0.000	0.000
150	150	2	0.860	0.940	0.052	0.009	0.000	0.000	0.000	0.000
151	151	2	0.792	0.885	0.103	0.000	0.013	0.000	0.000	0.000
152	152	2	0.889	0.946	0.054	0.000	0.000	0.000	0.000	0.000
153	153	2	0.908	0.987	0.013	0.000	0.000	0.000	0.000	0.000
154	154	2	0.894	0.966	0.034	0.000	0.000	0.000	0.000	0.000
155	155	2	0.865	0.813	0.125	0.018	0.000	0.027	0.018	0.000
156	156	2	0.902	0.901	0.099	0.000	0.000	0.000	0.000	0.000
157	157	2	0.802	0.988	0.012	0.000	0.000	0.000	0.000	0.000
158	158	2	0.823	0.822	0.137	0.027	0.000	0.014	0.000	0.000
159	159	2	0.863	0.977	0.023	0.000	0.000	0.000	0.000	0.000
160	160	2	0.958	0.964	0.036	0.000	0.000	0.000	0.000	0.000
161	161	2	0.788	0.833	0.135	0.026	0.000	0.000	0.006	0.000
162	162	2	0.818	0.838	0.149	0.014	0.000	0.000	0.000	0.000
163	163	2	0.789	0.816	0.149	0.023	0.011	0.000	0.000	0.000
164	164	2	0.816	0.875	0.105	0.007	0.013	0.000	0.000	0.000
165	165	2	0.796	0.775	0.125	0.025	0.025	0.025	0.025	0.000
166	166	2	0.660	0.925	0.068	0.000	0.004	0.004	0.000	0.000
167	167	2	0.714	0.880	0.090	0.009	0.009	0.013	0.000	0.000
168	168	2	0.654	0.941	0.052	0.003	0.003	0.000	0.000	0.000
169	169	2	0.699	0.876	0.096	0.012	0.008	0.008	0.000	0.000
170	170	2	0.671	0.849	0.088	0.029	0.007	0.022	0.004	0.000
171	171	2	0.731	0.854	0.100	0.023	0.018	0.005	0.000	0.000
172	172	2	0.776	0.944	0.044	0.011	0.000	0.000	0.000	0.000
173	173	2	0.682	0.909	0.072	0.015	0.000	0.004	0.000	0.000
174	174	2	0.628	0.916	0.058	0.010	0.010	0.006	0.000	0.000
175	175	2	0.640	0.896	0.077	0.007	0.007	0.007	0.003	0.003
176	176	2	0.657	0.930	0.039	0.014	0.007	0.004	0.007	0.000
177	177	2	0.675	0.907	0.082	0.004	0.004	0.000	0.004	0.000
178	178	2	0.736	0.968	0.028	0.005	0.000	0.000	0.000	0.000

179	179	2	0.657	0.894	0.099	0.004	0.000	0.000	0.004	0.000
180	180	2	0.751	0.971	0.029	0.000	0.000	0.000	0.000	0.000
181	181	2	0.706	0.955	0.041	0.004	0.000	0.000	0.000	0.000
182	182	2	0.591	0.965	0.035	0.000	0.000	0.000	0.000	0.000
183	183	2	0.656	0.905	0.081	0.004	0.004	0.004	0.000	0.004
184	184	2	0.688	0.984	0.018	0.011	0.004	0.004	0.000	0.000
185	185	2	0.595	0.970	0.027	0.000	0.003	0.000	0.000	0.000
186	186	2	0.602	0.973	0.015	0.003	0.009	0.000	0.000	0.000
187	187	2	0.715	0.960	0.035	0.004	0.000	0.000	0.000	0.000
188	188	2	0.646	0.961	0.028	0.007	0.004	0.000	0.000	0.000
189	189	2	0.664	0.971	0.029	0.000	0.000	0.000	0.000	0.000
190	190	2	0.851	0.975	0.025	0.000	0.000	0.000	0.000	0.000
191	191	2	0.796	0.987	0.013	0.000	0.000	0.000	0.000	0.000
192	192	2	0.771	0.810	0.132	0.037	0.005	0.011	0.005	0.000
193	193	2	0.532	0.845	0.120	0.008	0.013	0.011	0.003	0.000
194	194	2	0.669	0.952	0.044	0.000	0.004	0.000	0.000	0.000
195	195	2	0.487	0.896	0.094	0.009	0.000	0.000	0.000	0.000
196	196	2	0.502	0.944	0.053	0.002	0.000	0.000	0.000	0.000
197	197	2	0.771	0.968	0.032	0.000	0.000	0.000	0.000	0.000
198	198	2	0.552	0.924	0.065	0.008	0.000	0.003	0.000	0.000
199	199	2	0.551	0.941	0.054	0.003	0.003	0.000	0.000	0.000
200	200	2	0.841	0.977	0.015	0.008	0.000	0.000	0.000	0.000
201	201	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
202	202	2	0.494	0.812	0.128	0.036	0.014	0.007	0.002	0.000
203	203	2	0.303	0.733	0.176	0.034	0.020	0.026	0.010	0.000
204	204	2	0.381	0.967	0.029	0.002	0.000	0.002	0.000	0.000
205	205	2	0.333	0.668	0.189	0.044	0.040	0.029	0.024	0.007
206	206	2	0.576	0.991	0.009	0.000	0.000	0.000	0.000	0.000
207	207	2	0.227	0.956	0.034	0.006	0.003	0.000	0.000	0.000
208	208	2	0.361	0.995	0.002	0.002	0.000	0.000	0.000	0.000
209	209	2	0.757	0.995	0.005	0.000	0.000	0.000	0.000	0.000
210	210	2	0.743	0.991	0.005	0.005	0.000	0.000	0.000	0.000
211	211	2	0.692	0.984	0.016	0.000	0.000	0.000	0.000	0.000
212	212	2	0.599	0.994	0.006	0.000	0.000	0.000	0.000	0.000
213	213	2	0.752	1.000	0.000	0.000	0.000	0.000	0.000	0.000
214	214	2	0.649	1.000	0.000	0.000	0.000	0.000	0.000	0.000
215	215	2	0.692	0.996	0.004	0.000	0.000	0.000	0.000	0.000
216	216	2	0.665	1.000	0.000	0.000	0.000	0.000	0.000	0.000
217	217	2	0.691	0.886	0.078	0.012	0.012	0.008	0.004	0.000
218	218	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
219	219	2	0.922	0.944	0.056	0.000	0.000	0.000	0.000	0.000
220	220	2	0.806	0.883	0.117	0.000	0.000	0.000	0.000	0.000
221	221	2	0.749	0.908	0.078	0.005	0.010	0.000	0.000	0.000
222	222	2	0.854	0.876	0.099	0.008	0.017	0.000	0.000	0.000
223	223	2	0.629	0.811	0.121	0.033	0.013	0.016	0.007	0.000
224	224	2	0.669	0.734	0.153	0.040	0.029	0.029	0.015	0.000
225	225	2	0.639	0.773	0.147	0.037	0.030	0.007	0.003	0.003
226	226	2	0.624	0.797	0.155	0.023	0.013	0.013	0.000	0.000
227	227	2	0.668	0.803	0.131	0.033	0.016	0.016	0.000	0.000
228	228	2	0.727	0.553	0.164	0.066	0.049	0.058	0.066	0.044
229	229	2	0.574	0.804	0.156	0.017	0.011	0.011	0.000	0.000
230	230	2	0.565	0.811	0.164	0.014	0.003	0.003	0.003	0.003
231	231	2	0.563	0.734	0.177	0.030	0.028	0.017	0.011	0.003
232	232	2	0.547	0.827	0.149	0.016	0.005	0.003	0.000	0.000
233	233	2	0.564	0.776	0.158	0.042	0.003	0.011	0.011	0.000
234	234	2	0.587	0.762	0.158	0.032	0.026	0.012	0.009	0.000
235	235	2	0.568	0.801	0.132	0.028	0.011	0.020	0.006	0.003
236	236	2	0.673	0.757	0.138	0.049	0.011	0.030	0.007	0.007
237	237	2	0.723	0.700	0.198	0.044	0.022	0.026	0.009	0.000
238	238	2	0.705	0.963	0.020	0.008	0.004	0.004	0.000	0.000

239	239	2	0.697	0.932	0.040	0.012	0.004	0.012	0.000	0.000
240	240	2	0.680	0.947	0.045	0.004	0.004	0.000	0.000	0.000
241	241	2	0.391	0.853	0.101	0.028	0.014	0.004	0.000	0.000
242	242	2	0.375	0.731	0.155	0.031	0.033	0.029	0.019	0.002
243	243	2	0.643	0.753	0.162	0.030	0.017	0.020	0.014	0.003
244	244	2	0.584	0.879	0.106	0.006	0.009	0.000	0.000	0.000
245	245	2	0.624	0.749	0.186	0.026	0.006	0.019	0.013	0.000
246	246	2	0.572	0.895	0.093	0.010	0.003	0.000	0.000	0.000
247	247	2	0.565	0.814	0.139	0.017	0.008	0.006	0.011	0.006
248	248	2	0.519	0.867	0.095	0.025	0.003	0.005	0.005	0.000
249	249	2	0.542	0.863	0.119	0.013	0.003	0.000	0.003	0.000
250	250	2	0.560	0.819	0.124	0.027	0.011	0.011	0.008	0.000
251	251	2	0.579	0.837	0.132	0.020	0.011	0.000	0.000	0.000
252	252	2	0.579	0.897	0.100	0.000	0.000	0.000	0.003	0.000
253	253	2	0.572	0.847	0.093	0.037	0.006	0.008	0.006	0.003
254	254	2	0.610	0.849	0.112	0.012	0.008	0.016	0.000	0.004
255	255	2	0.628	0.815	0.146	0.010	0.016	0.000	0.013	0.000

EOT::

LIST TAPPERF3
===> LIST TAPPERF3

1	1	3	0.737	0.872	0.101	0.005	0.018	0.005	0.000	0.000
2	2	3	0.620	0.787	0.133	0.029	0.019	0.019	0.010	0.003
3	3	3	0.673	0.756	0.159	0.030	0.026	0.022	0.004	0.004
4	4	3	0.614	0.784	0.125	0.038	0.022	0.019	0.008	0.008
5	5	3	0.600	0.695	0.157	0.060	0.018	0.036	0.024	0.009
6	6	3	0.657	0.775	0.134	0.028	0.014	0.025	0.014	0.011
7	7	3	0.609	0.719	0.204	0.028	0.025	0.015	0.009	0.000
8	8	3	0.660	0.772	0.121	0.039	0.028	0.018	0.014	0.007
9	9	3	0.566	0.805	0.131	0.028	0.017	0.017	0.003	0.000
10	10	3	0.819	0.887	0.147	0.053	0.027	0.047	0.033	0.007
11	11	3	0.739	0.731	0.176	0.028	0.028	0.014	0.023	0.000
12	12	3	0.640	0.714	0.155	0.034	0.027	0.020	0.024	0.027
13	13	3	0.667	0.772	0.112	0.036	0.022	0.025	0.014	0.018
14	14	3	0.711	0.724	0.146	0.033	0.033	0.033	0.025	0.004
15	15	3	0.686	0.695	0.162	0.046	0.035	0.039	0.015	0.008
16	16	3	0.607	0.834	0.111	0.022	0.015	0.012	0.003	0.003
17	17	3	0.614	0.707	0.183	0.047	0.028	0.013	0.022	0.000
18	18	3	0.459	0.859	0.096	0.013	0.013	0.007	0.009	0.002
19	19	3	0.550	0.699	0.172	0.040	0.030	0.032	0.024	0.003
20	20	3	0.426	0.648	0.193	0.039	0.039	0.034	0.028	0.019
21	21	3	0.583	0.791	0.113	0.026	0.029	0.017	0.020	0.003
22	22	3	0.475	0.735	0.157	0.016	0.028	0.037	0.018	0.009
23	23	3	0.476	0.684	0.173	0.062	0.030	0.028	0.016	0.007
24	24	3	0.542	0.710	0.161	0.047	0.026	0.034	0.016	0.005
25	25	3	0.530	0.725	0.175	0.026	0.023	0.026	0.021	0.005
26	26	3	0.652	0.719	0.177	0.052	0.021	0.010	0.010	0.010
27	27	3	0.693	0.724	0.126	0.043	0.039	0.020	0.031	0.016
28	28	3	0.580	0.643	0.207	0.043	0.026	0.040	0.029	0.012
29	29	3	0.740	0.777	0.116	0.028	0.009	0.023	0.023	0.023
30	30	3	0.787	0.710	0.114	0.051	0.011	0.028	0.057	0.028
31	31	3	0.757	0.736	0.090	0.035	0.020	0.060	0.020	0.040
32	32	3	0.675	0.729	0.126	0.045	0.015	0.037	0.026	0.022
33	33	3	0.698	0.784	0.116	0.036	0.024	0.028	0.008	0.004
34	34	3	0.655	0.775	0.130	0.032	0.007	0.018	0.032	0.007
35	35	3	0.545	0.732	0.178	0.029	0.029	0.021	0.011	0.000
36	36	3	0.643	0.720	0.184	0.050	0.008	0.034	0.004	0.000
37	37	3	0.670	0.718	0.147	0.029	0.026	0.044	0.029	0.007
38	38	3	0.666	0.761	0.120	0.036	0.022	0.033	0.014	0.014
39	39	3	0.674	0.744	0.156	0.019	0.030	0.026	0.011	0.015
40	40	3	0.651	0.782	0.159	0.028	0.010	0.014	0.007	0.000
41	41	3	0.659	0.787	0.110	0.053	0.021	0.018	0.007	0.004
42	42	3	0.618	0.690	0.130	0.035	0.025	0.060	0.041	0.019
43	43	3	0.675	0.781	0.119	0.026	0.022	0.026	0.022	0.004
44	44	3	0.651	0.734	0.173	0.045	0.010	0.028	0.007	0.003
45	45	3	0.560	0.753	0.148	0.038	0.027	0.016	0.014	0.003
46	46	3	0.889	0.747	0.132	0.047	0.018	0.031	0.027	0.000
47	47	3	0.668	0.755	0.153	0.047	0.018	0.018	0.007	0.000
48	48	3	0.624	0.744	0.184	0.029	0.010	0.023	0.006	0.003
49	49	3	0.614	0.799	0.135	0.031	0.022	0.003	0.009	0.000
50	50	3	0.605	0.657	0.177	0.046	0.034	0.037	0.024	0.024
51	51	3	0.651	0.785	0.138	0.021	0.024	0.014	0.010	0.007
52	52	3	0.652	0.788	0.118	0.028	0.031	0.017	0.010	0.007
53	53	3	0.647	0.699	0.140	0.062	0.021	0.027	0.041	0.010
54	54	3	0.558	0.742	0.162	0.030	0.025	0.022	0.011	0.008
55	55	3	0.671	0.757	0.147	0.037	0.037	0.018	0.004	0.000
56	56	3	0.707	0.719	0.157	0.045	0.017	0.025	0.025	0.012
57	57	3	0.519	0.730	0.136	0.035	0.048	0.033	0.015	0.003
58	58	3	0.651	0.730	0.163	0.052	0.017	0.024	0.010	0.003

59	59	3	0.656	0.758	0.151	0.025	0.011	0.018	0.035	0.004
60	60	3	0.617	0.663	0.160	0.051	0.029	0.035	0.038	0.022
61	61	3	0.634	0.786	0.155	0.024	0.012	0.018	0.006	0.000
62	62	3	0.727	0.735	0.111	0.071	0.018	0.035	0.018	0.013
63	63	3	0.807	0.731	0.119	0.031	0.031	0.044	0.019	0.025
64	64	3	0.814	0.740	0.078	0.065	0.039	0.019	0.039	0.019
65	65	3	0.728	0.640	0.240	0.000	0.040	0.080	0.000	0.000
66	66	3	0.796	0.775	0.148	0.030	0.030	0.006	0.006	0.006
67	67	3	0.722	0.731	0.137	0.062	0.022	0.022	0.013	0.013
68	68	3	0.743	0.742	0.127	0.028	0.028	0.033	0.033	0.009
69	69	3	0.806	0.689	0.168	0.037	0.043	0.012	0.037	0.012
70	70	3	0.771	0.688	0.143	0.053	0.026	0.048	0.032	0.011
71	71	3	0.748	0.656	0.182	0.043	0.019	0.043	0.043	0.014
72	72	3	0.592	0.736	0.125	0.042	0.024	0.039	0.033	0.003
73	73	3	0.705	0.705	0.164	0.045	0.020	0.041	0.016	0.008
74	74	3	0.756	0.743	0.158	0.030	0.025	0.025	0.020	0.000
75	75	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	76	3	0.672	0.752	0.137	0.030	0.033	0.030	0.019	0.000
77	77	3	0.705	0.676	0.160	0.045	0.057	0.025	0.020	0.016
78	78	3	0.678	0.760	0.082	0.026	0.037	0.045	0.034	0.015
79	79	3	0.649	0.821	0.111	0.039	0.004	0.014	0.007	0.004
80	80	3	0.547	0.821	0.120	0.029	0.016	0.008	0.003	0.003
81	81	3	0.673	0.790	0.118	0.011	0.022	0.030	0.022	0.007
82	82	3	0.633	0.779	0.122	0.030	0.030	0.020	0.017	0.003
83	83	3	0.661	0.779	0.136	0.018	0.025	0.021	0.018	0.004
84	84	3	0.605	0.804	0.125	0.021	0.021	0.018	0.009	0.000
85	85	3	0.641	0.741	0.168	0.027	0.037	0.020	0.003	0.003
86	86	3	0.667	0.815	0.123	0.029	0.011	0.011	0.011	0.000
87	87	3	0.641	0.801	0.135	0.024	0.030	0.007	0.003	0.000
88	88	3	0.538	0.840	0.115	0.016	0.016	0.005	0.008	0.000
89	89	3	0.646	0.829	0.130	0.010	0.014	0.007	0.007	0.003
90	90	3	0.655	0.799	0.151	0.022	0.007	0.007	0.011	0.004
91	91	3	0.637	0.783	0.143	0.027	0.017	0.020	0.010	0.000
92	92	3	0.686	0.792	0.119	0.027	0.023	0.015	0.008	0.015
93	93	3	0.646	0.812	0.123	0.038	0.003	0.014	0.010	0.000
94	94	3	0.605	0.743	0.165	0.037	0.015	0.028	0.009	0.003
95	95	3	0.617	0.814	0.145	0.028	0.006	0.003	0.003	0.000
96	96	3	0.595	0.794	0.143	0.036	0.015	0.012	0.000	0.000
97	97	3	0.597	0.788	0.127	0.027	0.015	0.019	0.015	0.008
98	98	3	0.604	0.787	0.143	0.024	0.012	0.027	0.006	0.000
99	99	3	0.620	0.723	0.194	0.029	0.016	0.022	0.016	0.000
100	100	3	0.675	0.799	0.141	0.026	0.007	0.011	0.011	0.004
101	101	3	0.656	0.764	0.148	0.035	0.035	0.011	0.004	0.004
102	102	3	0.685	0.793	0.153	0.019	0.011	0.008	0.011	0.004
103	103	3	0.623	0.752	0.164	0.029	0.006	0.023	0.013	0.013
104	104	3	0.605	0.798	0.126	0.031	0.028	0.015	0.003	0.000
105	105	3	0.681	0.829	0.099	0.034	0.019	0.011	0.000	0.008
106	106	3	0.659	0.723	0.163	0.021	0.025	0.043	0.014	0.011
107	107	3	0.606	0.834	0.095	0.037	0.015	0.012	0.003	0.003
108	108	3	0.647	0.743	0.168	0.017	0.014	0.038	0.017	0.003
109	109	3	0.701	0.781	0.153	0.021	0.017	0.025	0.004	0.000
110	110	3	0.618	0.756	0.168	0.044	0.006	0.013	0.009	0.003
111	111	3	0.628	0.731	0.146	0.045	0.023	0.039	0.013	0.003
112	112	3	0.615	0.755	0.179	0.019	0.019	0.016	0.013	0.000
113	113	3	0.624	0.778	0.154	0.029	0.013	0.019	0.003	0.003
114	114	3	0.544	0.822	0.119	0.013	0.021	0.013	0.003	0.008
115	115	3	0.635	0.844	0.093	0.030	0.010	0.003	0.020	0.000
116	116	3	0.541	0.850	0.105	0.013	0.005	0.013	0.008	0.005
117	117	3	0.648	0.767	0.118	0.028	0.028	0.042	0.010	0.007
118	118	3	0.613	0.809	0.087	0.044	0.012	0.019	0.022	0.006

119	119	3	0.634	0.729	0.158	0.046	0.023	0.020	0.017	0.007
120	120	3	0.602	0.754	0.140	0.027	0.012	0.046	0.012	0.009
121	121	3	0.675	0.866	0.086	0.007	0.015	0.015	0.007	0.004
122	122	3	0.698	0.704	0.160	0.049	0.019	0.049	0.012	0.006
123	123	3	0.637	0.750	0.123	0.037	0.017	0.023	0.033	0.017
124	124	3	0.712	0.793	0.127	0.034	0.013	0.013	0.021	0.000
125	125	3	0.683	0.844	0.118	0.015	0.004	0.015	0.004	0.000
126	126	3	0.714	0.675	0.154	0.064	0.021	0.043	0.026	0.017
127	127	3	0.696	0.776	0.114	0.024	0.020	0.041	0.020	0.004
128	128	3	0.682	0.760	0.137	0.053	0.019	0.015	0.015	0.000
129	129	3	0.659	0.783	0.149	0.032	0.007	0.018	0.004	0.007
130	130	3	0.654	0.763	0.113	0.046	0.011	0.035	0.021	0.011
131	131	3	0.167	0.884	0.077	0.012	0.009	0.006	0.010	0.003
132	132	3	0.839	0.750	0.135	0.000	0.019	0.029	0.048	0.019
133	133	3	0.831	0.993	0.007	0.000	0.000	0.000	0.000	0.000
134	134	3	0.719	0.987	0.009	0.004	0.000	0.000	0.000	0.000
135	135	3	0.399	0.966	0.024	0.008	0.002	0.000	0.000	0.000
136	136	3	0.816	0.796	0.118	0.020	0.026	0.013	0.026	0.000
137	137	3	0.807	0.806	0.150	0.006	0.006	0.019	0.012	0.000
138	138	3	0.787	0.722	0.159	0.040	0.028	0.034	0.011	0.006
139	139	3	0.815	0.876	0.072	0.026	0.007	0.020	0.000	0.000
140	140	3	0.719	0.720	0.164	0.069	0.017	0.009	0.017	0.004
141	141	3	0.801	0.757	0.155	0.034	0.014	0.027	0.014	0.000
142	142	3	0.769	0.906	0.089	0.000	0.000	0.005	0.000	0.000
143	143	3	0.706	0.905	0.058	0.008	0.016	0.012	0.000	0.000
144	144	3	0.751	0.820	0.098	0.024	0.005	0.044	0.010	0.000
145	145	3	0.839	0.985	0.008	0.000	0.008	0.000	0.000	0.000
146	146	3	0.830	0.991	0.000	0.009	0.000	0.000	0.000	0.000
147	147	3	0.993	0.833	0.000	0.000	0.000	0.167	0.000	0.000
148	148	3	0.915	0.886	0.086	0.014	0.014	0.000	0.000	0.000
149	149	3	0.839	0.962	0.038	0.000	0.000	0.000	0.000	0.000
150	150	3	0.993	0.833	0.000	0.167	0.000	0.000	0.000	0.000
151	151	3	0.837	0.868	0.113	0.019	0.000	0.000	0.000	0.000
152	152	3	0.787	0.898	0.068	0.017	0.017	0.000	0.000	0.000
153	153	3	0.965	0.828	0.172	0.000	0.000	0.000	0.000	0.000
154	154	3	0.937	0.942	0.000	0.019	0.019	0.019	0.000	0.000
155	155	3	0.992	0.857	0.000	0.000	0.000	0.000	0.143	0.000
156	156	3	0.926	0.869	0.082	0.049	0.000	0.000	0.000	0.000
157	157	3	0.924	0.968	0.032	0.000	0.000	0.000	0.000	0.000
158	158	3	0.979	0.941	0.000	0.000	0.000	0.059	0.000	0.000
159	159	3	0.824	0.946	0.054	0.000	0.000	0.000	0.000	0.000
160	160	3	0.975	0.933	0.000	0.000	0.000	0.000	0.067	0.000
161	161	3	0.963	0.963	0.037	0.000	0.000	0.000	0.000	0.000
162	162	3	0.981	0.875	0.125	0.000	0.000	0.000	0.000	0.000
163	163	3	0.946	1.000	0.000	0.000	0.000	0.000	0.000	0.000
164	164	3	0.977	0.895	0.105	0.000	0.000	0.000	0.000	0.000
165	165	3	0.984	1.000	0.000	0.000	0.000	0.000	0.000	0.000
166	166	3	0.667	0.872	0.106	0.011	0.007	0.004	0.000	0.000
167	167	3	0.686	0.850	0.098	0.008	0.004	0.028	0.008	0.004
168	168	3	0.687	0.903	0.076	0.008	0.008	0.004	0.004	0.004
169	169	3	0.827	0.930	0.056	0.000	0.007	0.007	0.000	0.000
170	170	3	0.677	0.793	0.132	0.019	0.019	0.023	0.015	0.000
171	171	3	0.724	0.784	0.132	0.048	0.018	0.018	0.000	0.000
172	172	3	0.866	0.900	0.073	0.018	0.000	0.009	0.000	0.000
173	173	3	0.706	0.893	0.070	0.025	0.008	0.004	0.000	0.000
174	174	3	0.737	0.922	0.060	0.009	0.005	0.000	0.005	0.000
175	175	3	0.731	0.937	0.054	0.005	0.000	0.005	0.000	0.000
176	176	3	0.763	0.944	0.041	0.005	0.010	0.000	0.000	0.000
177	177	3	0.672	0.875	0.077	0.015	0.018	0.007	0.007	0.000
178	178	3	0.882	0.969	0.031	0.000	0.000	0.000	0.000	0.000

179	179	3	0.845	0.953	0.047	0.000	0.000	0.000	0.000	0.000
180	180	3	0.900	0.928	0.060	0.000	0.012	0.000	0.000	0.000
181	181	3	0.861	0.965	0.009	0.017	0.000	0.009	0.000	0.000
182	182	3	0.818	1.000	0.000	0.000	0.000	0.000	0.000	0.000
183	183	3	0.692	0.878	0.102	0.012	0.004	0.004	0.000	0.000
184	184	3	0.725	0.908	0.075	0.004	0.009	0.004	0.000	0.000
185	185	3	0.669	0.956	0.029	0.011	0.000	0.004	0.000	0.000
186	186	3	0.696	0.968	0.028	0.004	0.000	0.000	0.000	0.000
187	187	3	0.858	0.932	0.060	0.000	0.009	0.000	0.000	0.000
188	188	3	0.840	0.958	0.042	0.000	0.000	0.000	0.000	0.000
189	189	3	0.812	0.904	0.090	0.006	0.000	0.000	0.000	0.000
190	190	3	0.935	0.943	0.038	0.019	0.000	0.000	0.000	0.000
191	191	3	0.875	0.978	0.022	0.000	0.000	0.000	0.000	0.000
192	192	3	0.963	0.968	0.032	0.000	0.000	0.000	0.000	0.000
193	193	3	0.836	0.882	0.103	0.000	0.007	0.007	0.000	0.000
194	194	3	0.900	0.964	0.036	0.000	0.000	0.000	0.000	0.000
195	195	3	0.748	0.909	0.067	0.014	0.010	0.000	0.000	0.000
196	196	3	0.778	0.902	0.082	0.016	0.000	0.000	0.000	0.000
197	197	3	0.865	0.955	0.045	0.000	0.000	0.000	0.000	0.000
198	198	3	0.828	0.937	0.056	0.007	0.000	0.000	0.000	0.000
199	199	3	0.766	0.897	0.098	0.000	0.000	0.005	0.000	0.000
200	200	3	0.893	0.933	0.056	0.000	0.011	0.000	0.000	0.000
201	201	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
202	202	3	0.794	0.935	0.053	0.006	0.006	0.000	0.000	0.000
203	203	3	0.472	0.776	0.156	0.048	0.008	0.006	0.006	0.000
204	204	3	0.425	0.881	0.098	0.015	0.002	0.004	0.000	0.000
205	205	3	0.391	0.739	0.142	0.024	0.036	0.022	0.026	0.010
206	206	3	0.493	0.943	0.053	0.005	0.000	0.000	0.000	0.000
207	207	3	0.332	0.953	0.036	0.002	0.002	0.007	0.000	0.000
208	208	3	0.394	0.967	0.031	0.002	0.000	0.000	0.000	0.000
209	209	3	0.571	0.966	0.031	0.003	0.000	0.000	0.000	0.000
210	210	3	0.638	0.937	0.060	0.000	0.003	0.000	0.000	0.000
211	211	3	0.496	0.966	0.024	0.005	0.002	0.000	0.002	0.000
212	212	3	0.490	0.966	0.034	0.000	0.000	0.000	0.000	0.000
213	213	3	0.666	0.960	0.040	0.000	0.000	0.000	0.000	0.000
214	214	3	0.553	0.940	0.043	0.011	0.003	0.003	0.000	0.000
215	215	3	0.658	1.000	0.000	0.000	0.000	0.000	0.000	0.000
216	216	3	0.528	0.997	0.003	0.000	0.000	0.000	0.000	0.000
217	217	3	0.635	0.867	0.100	0.013	0.003	0.003	0.010	0.003
218	218	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
219	219	3	0.767	0.909	0.080	0.000	0.011	0.000	0.000	0.000
220	220	3	0.695	0.866	0.101	0.007	0.027	0.000	0.000	0.000
221	221	3	0.864	0.893	0.089	0.000	0.009	0.009	0.000	0.000
222	222	3	0.989	1.000	0.000	0.000	0.000	0.000	0.000	0.000
223	223	3	0.659	0.733	0.153	0.039	0.032	0.018	0.021	0.004
224	224	3	0.696	0.663	0.183	0.040	0.052	0.016	0.028	0.020
225	225	3	0.701	0.713	0.186	0.057	0.016	0.016	0.008	0.004
226	226	3	0.633	0.762	0.149	0.036	0.020	0.020	0.010	0.003
227	227	3	0.753	0.698	0.226	0.000	0.038	0.019	0.000	0.019
228	228	3	0.520	0.662	0.179	0.056	0.020	0.038	0.030	0.015
229	229	3	0.629	0.733	0.160	0.036	0.020	0.036	0.016	0.000
230	230	3	0.628	0.747	0.130	0.049	0.032	0.026	0.013	0.003
231	231	3	0.669	0.712	0.168	0.040	0.018	0.026	0.029	0.007
232	232	3	0.653	0.700	0.167	0.052	0.031	0.017	0.021	0.010
233	233	3	0.640	0.682	0.187	0.048	0.031	0.031	0.017	0.003
234	234	3	0.656	0.701	0.197	0.039	0.021	0.021	0.014	0.007
235	235	3	0.674	0.751	0.141	0.026	0.030	0.030	0.015	0.007
236	236	3	0.727	0.777	0.121	0.036	0.027	0.027	0.004	0.009
237	237	3	0.781	0.704	0.179	0.067	0.022	0.011	0.017	0.000
238	238	3	0.690	0.898	0.066	0.004	0.016	0.004	0.012	0.000

239	239	3	0.724	0.900	0.077	0.005	0.014	0.005	0.000	0.000
240	240	3	0.691	0.898	0.070	0.020	0.008	0.004	0.000	0.000
241	241	3	0.628	0.906	0.071	0.016	0.000	0.006	0.000	0.000
242	242	3	0.568	0.846	0.115	0.011	0.014	0.008	0.006	0.000
243	243	3	0.692	0.774	0.128	0.035	0.035	0.018	0.004	0.004
244	244	3	0.627	0.839	0.112	0.033	0.013	0.003	0.000	0.000
245	245	3	0.692	0.753	0.149	0.020	0.012	0.039	0.024	0.004
246	246	3	0.638	0.821	0.116	0.024	0.012	0.020	0.008	0.000
247	247	3	0.623	0.728	0.173	0.035	0.013	0.029	0.013	0.010
248	248	3	0.614	0.775	0.144	0.044	0.009	0.019	0.009	0.000
249	249	3	0.664	0.745	0.176	0.047	0.011	0.011	0.011	0.000
250	250	3	0.608	0.772	0.148	0.019	0.023	0.028	0.006	0.003
251	251	3	0.688	0.775	0.128	0.043	0.023	0.019	0.004	0.008
252	252	3	0.661	0.819	0.096	0.046	0.011	0.011	0.018	0.000
253	253	3	0.668	0.749	0.149	0.044	0.015	0.029	0.015	0.000
254	254	3	0.628	0.767	0.118	0.038	0.019	0.034	0.019	0.004
255	255	3	0.643	0.722	0.186	0.024	0.031	0.014	0.020	0.003

EOT;;

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LIST TAPPERE4
===> LIST TAPPERE4
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1	1	4	0.807	0.852	0.097	0.013	0.013	0.006	0.013	0.006
2	2	4	0.708	0.720	0.142	0.050	0.033	0.025	0.021	0.008
3	3	4	0.751	0.765	0.132	0.020	0.034	0.044	0.005	0.000
4	4	4	0.753	0.752	0.119	0.059	0.020	0.035	0.015	0.000
5	5	4	0.735	0.756	0.152	0.032	0.018	0.018	0.005	0.018
6	6	4	0.704	0.649	0.190	0.025	0.025	0.058	0.041	0.012
7	7	4	0.638	0.811	0.142	0.014	0.017	0.010	0.007	0.000
8	8	4	0.713	0.677	0.149	0.055	0.043	0.034	0.021	0.021
9	9	4	0.586	0.829	0.130	0.015	0.012	0.012	0.003	0.000
10	10	4	0.769	0.730	0.132	0.026	0.016	0.048	0.037	0.011
11	11	4	0.759	0.787	0.137	0.020	0.015	0.025	0.015	0.000
12	12	4	0.731	0.655	0.132	0.050	0.041	0.064	0.018	0.041
13	13	4	0.718	0.688	0.186	0.035	0.022	0.030	0.026	0.013
14	14	4	0.710	0.755	0.160	0.021	0.013	0.034	0.017	0.000
15	15	4	0.742	0.754	0.123	0.038	0.019	0.019	0.019	0.028
16	16	4	0.525	0.840	0.116	0.013	0.005	0.013	0.013	0.000
17	17	4	0.502	0.861	0.101	0.007	0.020	0.005	0.005	0.000
18	18	4	0.419	0.812	0.108	0.015	0.021	0.017	0.015	0.013
19	19	4	0.669	0.712	0.148	0.044	0.015	0.030	0.030	0.022
20	20	4	0.740	0.705	0.162	0.033	0.029	0.052	0.005	0.014
21	21	4	0.664	0.818	0.109	0.029	0.018	0.011	0.007	0.007
22	22	4	0.562	0.746	0.159	0.022	0.025	0.022	0.020	0.006
23	23	4	0.685	0.787	0.128	0.031	0.019	0.016	0.004	0.016
24	24	4	0.732	0.717	0.151	0.050	0.037	0.018	0.018	0.009
25	25	4	0.568	0.708	0.147	0.037	0.017	0.034	0.034	0.023
26	26	4	0.732	0.653	0.189	0.042	0.021	0.032	0.042	0.021
27	27	4	0.728	0.671	0.171	0.036	0.036	0.050	0.023	0.014
28	28	4	0.710	0.616	0.181	0.038	0.055	0.046	0.046	0.017
29	29	4	0.722	0.753	0.123	0.044	0.022	0.026	0.022	0.009
30	30	4	0.742	0.739	0.142	0.019	0.014	0.038	0.024	0.024
31	31	4	0.733	0.721	0.137	0.055	0.027	0.018	0.032	0.009
32	32	4	0.707	0.708	0.129	0.025	0.025	0.050	0.042	0.021
33	33	4	0.743	0.719	0.157	0.052	0.024	0.029	0.014	0.005
34	34	4	0.725	0.693	0.187	0.044	0.018	0.022	0.018	0.018
35	35	4	0.556	0.840	0.105	0.039	0.008	0.006	0.003	0.000
36	36	4	0.691	0.723	0.165	0.039	0.015	0.034	0.019	0.005
37	37	4	0.734	0.724	0.171	0.037	0.032	0.018	0.014	0.005
38	38	4	0.693	0.769	0.124	0.048	0.008	0.024	0.024	0.004
39	39	4	0.717	0.698	0.164	0.022	0.030	0.047	0.022	0.017
40	40	4	0.698	0.769	0.138	0.024	0.016	0.032	0.016	0.004
41	41	4	0.722	0.758	0.110	0.053	0.009	0.044	0.022	0.004
42	42	4	0.708	0.757	0.138	0.017	0.025	0.025	0.021	0.017
43	43	4	0.694	0.768	0.132	0.016	0.028	0.036	0.020	0.000
44	44	4	0.752	0.650	0.172	0.049	0.039	0.054	0.015	0.020
45	45	4	0.612	0.821	0.113	0.035	0.022	0.009	0.000	0.000
46	46	4	0.728	0.758	0.152	0.036	0.018	0.013	0.022	0.000
47	47	4	0.736	0.727	0.134	0.051	0.037	0.028	0.023	0.000
48	48	4	0.729	0.695	0.150	0.036	0.064	0.014	0.027	0.014
49	49	4	0.691	0.759	0.154	0.040	0.020	0.020	0.008	0.000
50	50	4	0.746	0.769	0.101	0.034	0.010	0.034	0.034	0.019
51	51	4	0.736	0.699	0.162	0.032	0.032	0.023	0.032	0.019
52	52	4	0.710	0.629	0.224	0.051	0.030	0.017	0.025	0.025
53	53	4	0.758	0.742	0.116	0.025	0.035	0.040	0.035	0.005
54	54	4	0.713	0.728	0.132	0.038	0.030	0.034	0.038	0.000
55	55	4	0.689	0.725	0.173	0.035	0.027	0.027	0.012	0.000
56	56	4	0.722	0.612	0.194	0.062	0.048	0.048	0.031	0.004
57	57	4	0.688	0.667	0.173	0.039	0.016	0.031	0.047	0.027
58	58	4	0.719	0.748	0.148	0.039	0.004	0.035	0.017	0.009

59	59	4	0.675	0.688	0.184	0.041	0.034	0.030	0.011	0.011
60	60	4	0.744	0.662	0.169	0.039	0.019	0.024	0.063	0.024
61	61	4	0.699	0.759	0.124	0.051	0.000	0.036	0.015	0.015
62	62	4	0.752	0.695	0.133	0.025	0.059	0.034	0.049	0.005
63	63	4	0.737	0.735	0.149	0.028	0.019	0.042	0.014	0.014
64	64	4	0.747	0.758	0.118	0.034	0.034	0.029	0.019	0.010
65	65	4	0.697	0.609	0.196	0.065	0.022	0.065	0.043	0.000
66	66	4	0.785	0.705	0.153	0.040	0.023	0.028	0.040	0.011
67	67	4	0.729	0.624	0.158	0.050	0.045	0.068	0.045	0.009
68	68	4	0.725	0.698	0.164	0.036	0.044	0.031	0.022	0.004
69	69	4	0.779	0.707	0.182	0.011	0.039	0.022	0.022	0.017
70	70	4	0.763	0.758	0.160	0.031	0.005	0.028	0.021	0.000
71	71	4	0.758	0.667	0.116	0.081	0.025	0.051	0.051	0.010
72	72	4	0.742	0.602	0.166	0.085	0.024	0.081	0.019	0.024
73	73	4	0.763	0.825	0.093	0.046	0.000	0.021	0.010	0.005
74	74	4	0.808	0.866	0.083	0.006	0.013	0.025	0.006	0.000
75	75	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	76	4	0.698	0.805	0.142	0.020	0.016	0.008	0.008	0.000
77	77	4	0.695	0.676	0.164	0.068	0.036	0.040	0.004	0.012
78	78	4	0.744	0.703	0.148	0.038	0.033	0.038	0.019	0.019
79	79	4	0.634	0.799	0.119	0.034	0.014	0.027	0.007	0.000
80	80	4	0.533	0.877	0.099	0.005	0.016	0.003	0.000	0.000
81	81	4	0.713	0.723	0.153	0.043	0.021	0.034	0.009	0.017
82	82	4	0.525	0.845	0.111	0.021	0.013	0.005	0.003	0.003
83	83	4	0.695	0.736	0.128	0.048	0.032	0.032	0.016	0.008
84	84	4	0.618	0.811	0.119	0.042	0.003	0.016	0.010	0.000
85	85	4	0.658	0.779	0.107	0.036	0.032	0.018	0.029	0.300
86	86	4	0.671	0.814	0.093	0.041	0.019	0.019	0.015	0.000
87	87	4	0.674	0.719	0.150	0.041	0.030	0.037	0.015	0.007
88	88	4	0.548	0.838	0.116	0.027	0.008	0.011	0.000	0.000
89	89	4	0.669	0.789	0.126	0.041	0.022	0.015	0.007	0.000
90	90	4	0.671	0.772	0.146	0.011	0.019	0.022	0.015	0.015
91	91	4	0.649	0.763	0.129	0.028	0.028	0.031	0.017	0.003
92	92	4	0.685	0.733	0.159	0.027	0.027	0.027	0.019	0.008
93	93	4	0.532	0.893	0.081	0.008	0.008	0.005	0.003	0.003
94	94	4	0.518	0.822	0.122	0.013	0.015	0.020	0.003	0.003
95	95	4	0.612	0.774	0.151	0.044	0.013	0.013	0.003	0.003
96	96	4	0.608	0.791	0.125	0.028	0.022	0.012	0.012	0.009
97	97	4	0.618	0.876	0.094	0.011	0.008	0.008	0.000	0.004
98	98	4	0.574	0.879	0.095	0.011	0.011	0.000	0.003	0.000
99	99	4	0.641	0.830	0.122	0.027	0.010	0.007	0.000	0.003
100	100	4	0.613	0.870	0.092	0.003	0.019	0.013	0.003	0.000
101	101	4	0.655	0.862	0.106	0.014	0.011	0.007	0.000	0.000
102	102	4	0.615	0.892	0.086	0.003	0.010	0.010	0.000	0.000
103	103	4	0.672	0.854	0.108	0.015	0.011	0.007	0.004	0.000
104	104	4	0.670	0.836	0.141	0.007	0.004	0.007	0.004	0.000
105	105	4	0.625	0.876	0.101	0.007	0.013	0.003	0.000	0.000
106	106	4	0.684	0.795	0.136	0.031	0.023	0.012	0.004	0.000
107	107	4	0.480	0.901	0.077	0.016	0.002	0.002	0.000	0.000
108	108	4	0.605	0.804	0.143	0.025	0.006	0.019	0.003	0.000
109	109	4	0.579	0.894	0.091	0.000	0.006	0.006	0.003	0.000
110	110	4	0.571	0.866	0.100	0.017	0.006	0.006	0.003	0.003
111	111	4	0.526	0.820	0.131	0.015	0.015	0.013	0.003	0.003
112	112	4	0.587	0.873	0.101	0.021	0.000	0.003	0.000	0.003
113	113	4	0.661	0.871	0.090	0.022	0.011	0.007	0.000	0.000
114	114	4	0.580	0.895	0.073	0.012	0.006	0.006	0.006	0.003
115	115	4	0.731	0.886	0.068	0.018	0.009	0.014	0.005	0.000
116	116	4	0.573	0.894	0.080	0.003	0.009	0.006	0.006	0.003
117	117	4	0.728	0.824	0.136	0.014	0.014	0.005	0.009	0.000
118	118	4	0.705	0.909	0.062	0.008	0.004	0.017	0.000	0.000

119	119	4	0.703	0.811	0.123	0.029	0.029	0.004	0.004	0.000
120	120	4	0.678	0.840	0.125	0.015	0.008	0.004	0.004	0.004
121	121	4	0.790	0.892	0.066	0.030	0.000	0.012	0.000	0.000
122	122	4	0.747	0.808	0.138	0.008	0.015	0.023	0.008	0.000
123	123	4	0.706	0.846	0.100	0.029	0.004	0.000	0.021	0.000
124	124	4	0.789	0.820	0.122	0.012	0.023	0.012	0.006	0.006
125	125	4	0.784	0.904	0.068	0.023	0.000	0.006	0.000	0.000
126	126	4	0.772	0.788	0.141	0.027	0.027	0.005	0.005	0.005
127	127	4	0.766	0.788	0.122	0.011	0.026	0.032	0.016	0.005
128	128	4	0.744	0.866	0.086	0.024	0.014	0.000	0.005	0.005
129	129	4	0.740	0.873	0.061	0.005	0.023	0.028	0.005	0.005
130	130	4	0.700	0.852	0.086	0.033	0.012	0.004	0.008	0.004
131	131	4	0.263	0.776	0.129	0.028	0.008	0.013	0.023	0.022
132	132	4	0.804	0.825	0.124	0.000	0.007	0.022	0.015	0.007
133	133	4	0.789	0.936	0.040	0.012	0.006	0.000	0.006	0.000
134	134	4	0.716	0.910	0.056	0.009	0.000	0.004	0.004	0.017
135	135	4	0.433	0.922	0.039	0.011	0.009	0.002	0.009	0.009
136	136	4	0.830	0.755	0.151	0.007	0.007	0.043	0.036	0.000
137	137	4	0.802	0.735	0.123	0.049	0.037	0.025	0.025	0.006
138	138	4	0.812	0.805	0.136	0.026	0.006	0.019	0.006	0.000
139	139	4	0.851	0.861	0.082	0.008	0.025	0.008	0.016	0.000
140	140	4	0.818	0.879	0.094	0.013	0.000	0.013	0.000	0.000
141	141	4	0.869	0.843	0.118	0.029	0.000	0.010	0.000	0.000
142	142	4	0.839	0.924	0.061	0.015	0.000	0.000	0.000	0.000
143	143	4	0.811	0.935	0.039	0.026	0.000	0.000	0.000	0.000
144	144	4	0.842	0.853	0.109	0.023	0.008	0.000	0.008	0.000
145	145	4	0.823	0.966	0.034	0.000	0.000	0.000	0.000	0.000
146	146	4	0.837	0.887	0.104	0.000	0.009	0.000	0.000	0.000
147	147	4	0.939	0.800	0.140	0.040	0.000	0.020	0.000	0.000
148	148	4	0.913	0.887	0.099	0.014	0.000	0.000	0.000	0.000
149	149	4	0.830	0.914	0.086	0.000	0.000	0.000	0.000	0.000
150	150	4	0.925	0.951	0.033	0.016	0.000	0.000	0.000	0.000
151	151	4	0.807	0.857	0.129	0.000	0.000	0.014	0.000	0.000
152	152	4	0.849	0.846	0.098	0.041	0.008	0.008	0.000	0.000
153	153	4	0.951	0.949	0.026	0.000	0.000	0.000	0.026	0.000
154	154	4	0.922	0.922	0.078	0.000	0.000	0.000	0.000	0.000
155	155	4	0.939	0.840	0.060	0.020	0.060	0.020	0.000	0.000
156	156	4	0.906	0.844	0.143	0.000	0.000	0.000	0.013	0.000
157	157	4	0.889	0.934	0.066	0.000	0.000	0.000	0.000	0.000
158	158	4	0.919	0.848	0.121	0.030	0.000	0.000	0.000	0.000
159	159	4	0.843	0.853	0.126	0.000	0.011	0.000	0.011	0.000
160	160	4	0.934	0.975	0.000	0.000	0.000	0.000	0.025	0.000
161	161	4	0.857	0.788	0.159	0.018	0.027	0.009	0.000	0.000
162	162	4	0.880	0.786	0.194	0.020	0.000	0.000	0.000	0.000
163	163	4	0.860	0.774	0.191	0.017	0.000	0.009	0.009	0.000
164	164	4	0.885	0.862	0.106	0.000	0.021	0.011	0.000	0.000
165	165	4	0.945	1.000	0.000	0.000	0.000	0.000	0.000	0.000
166	166	4	0.755	0.930	0.025	0.010	0.020	0.010	0.005	0.000
167	167	4	0.783	0.881	0.074	0.011	0.017	0.011	0.006	0.000
168	168	4	0.808	0.962	0.019	0.006	0.006	0.000	0.006	0.000
169	169	4	0.842	0.883	0.078	0.031	0.000	0.008	0.000	0.000
170	170	4	0.814	0.914	0.059	0.000	0.020	0.007	0.000	0.000
171	171	4	0.842	0.883	0.055	0.008	0.023	0.016	0.016	0.000
172	172	4	0.853	0.949	0.025	0.017	0.000	0.008	0.000	0.000
173	173	4	0.840	0.893	0.092	0.015	0.000	0.000	0.000	0.000
174	174	4	0.770	0.915	0.074	0.011	0.000	0.000	0.000	0.000
175	175	4	0.784	0.898	0.085	0.006	0.000	0.011	0.000	0.000
176	176	4	0.817	0.947	0.047	0.000	0.000	0.007	0.000	0.000
177	177	4	0.830	0.942	0.036	0.007	0.000	0.000	0.014	0.000
178	178	4	0.839	0.939	0.046	0.008	0.008	0.000	0.000	0.000

179	179	4	0.778	0.879	0.104	0.011	0.005	0.000	0.000	0.000
180	180	4	0.859	0.939	0.061	0.000	0.000	0.000	0.000	0.000
181	181	4	0.786	0.954	0.040	0.000	0.000	0.006	0.000	0.000
182	182	4	0.706	0.973	0.027	0.000	0.000	0.000	0.000	0.000
183	183	4	0.785	0.949	0.040	0.011	0.000	0.000	0.000	0.000
184	184	4	0.782	0.955	0.034	0.006	0.000	0.006	0.000	0.000
185	185	4	0.696	0.976	0.024	0.000	0.000	0.000	0.000	0.000
186	186	4	0.715	0.974	0.013	0.013	0.000	0.000	0.000	0.000
187	187	4	0.744	0.962	0.033	0.005	0.000	0.000	0.000	0.000
188	188	4	0.778	0.954	0.029	0.006	0.011	0.000	0.000	0.000
189	189	4	0.736	0.935	0.065	0.000	0.000	0.000	0.000	0.000
190	190	4	0.909	0.986	0.014	0.000	0.000	0.000	0.000	0.000
191	191	4	0.864	0.964	0.036	0.000	0.000	0.000	0.000	0.000
192	192	4	0.820	0.796	0.156	0.007	0.027	0.007	0.007	0.000
193	193	4	0.638	0.754	0.143	0.041	0.027	0.027	0.003	0.003
194	194	4	0.736	0.870	0.106	0.005	0.005	0.009	0.005	0.000
195	195	4	0.540	0.785	0.157	0.029	0.016	0.008	0.005	0.000
196	196	4	0.595	0.858	0.118	0.012	0.003	0.008	0.003	0.000
197	197	4	0.799	0.988	0.012	0.000	0.000	0.000	0.000	0.000
198	198	4	0.611	0.815	0.144	0.019	0.003	0.016	0.003	0.000
199	199	4	0.583	0.862	0.114	0.009	0.009	0.003	0.003	0.000
200	200	4	0.808	0.987	0.013	0.000	0.000	0.000	0.000	0.000
201	201	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
202	202	4	0.623	0.694	0.208	0.052	0.013	0.020	0.013	0.000
203	203	4	0.295	0.589	0.216	0.079	0.043	0.031	0.026	0.016
204	204	4	0.293	0.810	0.131	0.024	0.014	0.018	0.005	0.000
205	205	4	0.237	0.431	0.232	0.098	0.061	0.088	0.059	0.031
206	206	4	0.487	0.957	0.036	0.002	0.000	0.005	0.000	0.000
207	207	4	0.168	0.918	0.060	0.013	0.003	0.003	0.003	0.000
208	208	4	0.256	0.990	0.010	0.000	0.000	0.000	0.000	0.000
209	209	4	0.595	0.994	0.006	0.000	0.000	0.000	0.000	0.000
210	210	4	0.578	0.936	0.052	0.009	0.003	0.000	0.000	0.000
211	211	4	0.523	0.956	0.036	0.008	0.000	0.000	0.000	0.000
212	212	4	0.494	0.973	0.020	0.002	0.005	0.000	0.000	0.000
213	213	4	0.612	0.981	0.016	0.003	0.000	0.000	0.000	0.000
214	214	4	0.568	0.955	0.040	0.003	0.003	0.000	0.000	0.000
215	215	4	0.489	1.000	0.000	0.000	0.000	0.000	0.000	0.000
216	216	4	0.413	1.000	0.000	0.000	0.000	0.000	0.000	0.000
217	217	4	0.825	0.902	0.077	0.007	0.014	0.000	0.000	0.000
218	218	4	0.593	0.750	0.208	0.042	0.000	0.000	0.000	0.000
219	219	4	0.822	0.787	0.107	0.040	0.027	0.027	0.013	0.000
220	220	4	0.848	0.880	0.108	0.000	0.012	0.000	0.000	0.000
221	221	4	0.837	0.887	0.105	0.008	0.000	0.000	0.000	0.000
222	222	4	0.897	0.857	0.131	0.000	0.012	0.000	0.000	0.000
223	223	4	0.710	0.755	0.110	0.055	0.017	0.051	0.004	0.008
224	224	4	0.690	0.689	0.161	0.012	0.039	0.059	0.020	0.020
225	225	4	0.703	0.778	0.132	0.025	0.012	0.029	0.021	0.004
226	226	4	0.704	0.731	0.169	0.021	0.017	0.033	0.025	0.004
227	227	4	0.729	0.719	0.140	0.035	0.000	0.035	0.053	0.018
228	228	4	0.752	0.631	0.182	0.049	0.025	0.049	0.044	0.020
229	229	4	0.675	0.756	0.184	0.030	0.008	0.011	0.008	0.004
230	230	4	0.650	0.829	0.140	0.014	0.003	0.007	0.007	0.000
231	231	4	0.681	0.747	0.153	0.034	0.019	0.034	0.011	0.000
232	232	4	0.673	0.843	0.093	0.030	0.026	0.004	0.000	0.004
233	233	4	0.643	0.777	0.158	0.024	0.017	0.014	0.007	0.003
234	234	4	0.672	0.732	0.164	0.048	0.022	0.011	0.019	0.004
235	235	4	0.708	0.812	0.155	0.004	0.008	0.013	0.004	0.004
236	236	4	0.728	0.680	0.153	0.059	0.005	0.059	0.032	0.014
237	237	4	0.825	0.797	0.098	0.042	0.021	0.028	0.014	0.000
238	238	4	0.817	0.940	0.047	0.007	0.000	0.007	0.000	0.000

239	239	4	0.819	0.959	0.027	0.000	0.007	0.007	0.000	0.000
240	240	4	0.768	0.942	0.047	0.005	0.005	0.000	0.000	0.000
241	241	4	0.525	0.715	0.188	0.033	0.031	0.023	0.008	0.003
242	242	4	0.454	0.626	0.195	0.054	0.031	0.054	0.034	0.007
243	243	4	0.702	0.736	0.149	0.013	0.047	0.017	0.034	0.004
244	244	4	0.573	0.841	0.104	0.032	0.012	0.000	0.009	0.003
245	245	4	0.717	0.720	0.151	0.043	0.039	0.030	0.004	0.013
246	246	4	0.553	0.899	0.088	0.003	0.006	0.003	0.000	0.000
247	247	4	0.664	0.822	0.127	0.018	0.011	0.011	0.011	0.000
248	248	4	0.600	0.841	0.131	0.006	0.003	0.012	0.006	0.000
249	249	4	0.640	0.864	0.105	0.014	0.010	0.007	0.000	0.000
250	250	4	0.645	0.838	0.117	0.027	0.003	0.007	0.007	0.000
251	251	4	0.648	0.861	0.118	0.014	0.007	0.000	0.000	0.000
252	252	4	0.543	0.930	0.053	0.005	0.005	0.005	0.000	0.000
253	253	4	0.632	0.831	0.120	0.013	0.020	0.013	0.003	0.000
254	254	4	0.671	0.847	0.096	0.024	0.024	0.010	0.000	0.000
255	255	4	0.724	0.827	0.102	0.022	0.018	0.013	0.013	0.004

EOT..

LIST TAPPERF5
===> LIST TAPPERF5

1	1	2	1	0.336	0.331	0.164	0.169
2	1	3	1	0.393	0.274	0.207	0.126
3	1	4	1	0.376	0.292	0.210	0.122
4	1	5	1	0.398	0.268	0.225	0.109
5	1	6	1	0.356	0.310	0.148	0.185
6	1	7	1	0.223	0.443	0.118	0.217
7	1	8	1	0.393	0.273	0.201	0.132
8	1	9	1	0.190	0.477	0.099	0.235
9	1	10	1	0.502	0.166	0.169	0.163
10	1	11	1	0.457	0.210	0.148	0.185
11	1	12	1	0.387	0.281	0.153	0.179
12	1	13	1	0.359	0.307	0.174	0.159
13	1	14	1	0.332	0.336	0.123	0.209
14	1	15	1	0.410	0.257	0.157	0.176
15	1	16	1	0.110	0.557	0.054	0.279
16	1	17	1	0.080	0.587	0.037	0.296
17	1	18	1	0.182	0.485	0.103	0.230
18	1	19	1	0.391	0.275	0.235	0.099
19	1	20	1	0.481	0.186	0.275	0.059
20	1	21	1	0.425	0.244	0.248	0.084
21	1	22	1	0.415	0.252	0.220	0.114
22	1	23	1	0.411	0.256	0.249	0.084
23	1	24	1	0.408	0.258	0.253	0.080
24	1	25	1	0.383	0.284	0.221	0.111
25	1	26	1	0.388	0.216	0.259	0.137
26	1	27	1	0.409	0.258	0.129	0.204
27	1	28	1	0.367	0.300	0.165	0.168
28	1	29	1	0.368	0.299	0.200	0.132
29	1	30	1	0.446	0.221	0.138	0.195
30	1	31	1	0.410	0.256	0.171	0.163
31	1	32	1	0.403	0.265	0.140	0.193
32	1	33	1	0.374	0.293	0.195	0.138
33	1	34	1	0.391	0.275	0.195	0.138
34	1	35	1	0.165	0.501	0.090	0.243
35	1	36	1	0.392	0.286	0.190	0.133
36	1	37	1	0.362	0.305	0.183	0.151
37	.	38	1	0.334	0.333	0.182	0.151
38	1	39	1	0.361	0.305	0.189	0.145
39	1	40	1	0.341	0.326	0.164	0.170
40	1	41	1	0.344	0.322	0.180	0.153
41	1	42	1	0.386	0.280	0.200	0.133
42	1	43	1	0.327	0.340	0.183	0.151
43	1	44	1	0.379	0.287	0.178	0.156
44	1	45	1	0.207	0.459	0.107	0.226
45	1	46	1	0.386	0.280	0.185	0.148
46	1	47	1	0.386	0.300	0.172	0.142
47	1	48	1	0.370	0.297	0.168	0.165
48	1	49	1	0.299	0.368	0.144	0.189
49	1	50	1	0.373	0.293	0.214	0.120
50	1	51	1	0.389	0.277	0.197	0.137
51	1	52	1	0.370	0.296	0.162	0.172
52	1	53	1	0.385	0.281	0.201	0.132
53	1	54	1	0.385	0.281	0.228	0.105
54	1	55	1	0.329	0.337	0.152	0.182
55	1	56	1	0.356	0.311	0.148	0.185
56	1	57	1	0.389	0.278	0.178	0.156
57	1	58	1	0.389	0.278	0.189	0.144
58	1	59	1	0.318	0.350	0.139	0.193

END

FILMED

2-83

DTIC